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Agricultural Applications and the Economic Impact of Patents on Plant Breeding

January 1988

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Report on

Agricultural Applications and the Economic Impact of Patents on Plant Breeding

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INTRODUCTION

Industry expects biotechnology to have major applications for crop agriculture and many applications will be offered to the farmer through modified plants and seeds. Companies in the US will require access to markets and to plant breeding to justify their research investments for these applications. Another key to realizing a reasonable return on these investments is the protection of discoveries from exploitation by others through trade secrets and patents. The private sectors' interest in protecting its discoveries is accompanied by public interests in providing a safe and abundant food supply. Because of this convergence of public and private interests, this report examines the impact of patents and selected other intellectual property rights on the plant and seed industries in the United States and considers the public interest implications of the changing environment for intellectual property rights related to plant breeding and biotechnology.

The Constitution of the United States empowers Congress to enact legislation which secures exclusive rights for inventors and authors for their discoveries and writings (Article I, Section 8). This followed more than 300 years of related laws and rights in Europe and can be traced back to 200 B.C. in Greece (Frumkin, 1945). The first enabling US patent law was passed in 1790, and patents issued by the US Patent and Trademark Office have provided the inducement for many industries to develop, for example, pharmaceuticals,

farm implements, steel and iron, aluminum, chemicals, and automobiles. Living organisms were initially excluded from patent protection because they were considered products of nature (Seay, 1985). Breaking with 140 years of history and experience, Congress in 1930 passed the Plant Patent Act which established special provisions under the general patent law by which asexually reproduced plants could be patented. Subsequently, inventors in the United States have been able to obtain patents on specific life forms, asexually propagated plant varieties, for almost 60 years.

In 1968, amendments to the Plant Patent Act were proposed to include sexually produced plant varieties. However, this initiative died in committee because a presidential commission on patents rejected the patent system as an appropriate mechanism for plant variety protection (Perrin, Hunnings and Ihnen, 1983) and scientists in the USDA and state agricultural experiment stations expressed concerns about patenting plant varieties (Ruttan, 1982). Eventually, a separate act, the Plant Variety Protection Act, was passed in 1970 to protect sexually produced, non-hybrid varieties. The features of this legislation are patent-like with important exceptions. For example, the Plant Variety Protection Office in the Department of Agriculture issues Plant Variety Protection Certificates, not patents, and there are exemptions which allow the use of protected varieties for research and allow farmers to retain seed from protected varieties for planting. The first Certificates issued under

the Plant Variety Protection Act will expire in 1991.

A feature common to the the Plant Patent and the Plant Variety Certificate is that only one claim, the variety, is granted. This is decidedly different than the general patents which can include, and usually do, multiple claims. This difference became important when the Supreme Court ruled in the Chakrabarty v. Diamond case in 1980 that a new bacterial life form made substantially by man could be patented under the general patent statutes if other criteria for awarding a patent were met (OTA, 1984). This became the official position of the Patent and Trademark Office.

In 1985, the Board of Patent Appeals ruled that general patents could be granted for plant varieties in the Ex Parte Hibberd case (Van Brunt, 1985). Companies now have opportunities to protect their plant discoveries and developments through 3 different patent or patent-like mechanisms based on 3 different, and not necessarily exclusive, statutes. Further, the opportunity to protect discoveries and developments as trade secrets continues and trademark protection is a separate but sometimes related mechanism with which to protect products.

It is important to trace the evolution of the seed and plant industry in the United States to consider the impact of patents on plant breeding. Colonists initially brought seeds and plants to America to overcome the expense and spoilage of importing food from Europe. Attempts to grow imported seeds were frequently disastrous, and colonists eventually planted

native crops which the Indians cultivated (Kloppenburg, 1985). After American independence, the introduction of foreign seeds to the United States continued through agricultural societies and immigrants. In 1819, the Federal government established its first organized program to introduce foreign plants and seeds. This program was operated by the Patent Office in the Department of Treasury which is especially interesting considering this report. This program established government involvement in the introduction and development of crop varieties which continues today. This program was transferred to the Department of Agriculture when it was established in 1862. This activity preceded the publication of Mendel's experiments which are the foundation of the discipline of genetics and its practical application to plant breeding. Breeding for improved crop varieties rather than selecting adapted varieties has occurred primarily during this century. These improved varieties are the foundation of the seed and plant industries which has a very important public component (Evenson, 1987a; Kloppenburg, 1985).

To anticipate decisions which companies will make regarding intellectual property rights it is important to understand the different industries which compose the seed and plant industry and the differences in protection offered by the applicable statutes. It is reasonable to assume that intellectual property does not have equal value for all industries, and the opportunities for patent or patent-like

protection clearly differ from plant to plant. That is, the opportunities for F1 hybrid corn are different than for soybeans although each crop is grown on large total acreage in the United States and often rotated with the other. Because of these differences, selected plant and seed industries are discussed to identify important issues related to intellectual property rights especially patents. These industries were examined by searching the literature for relevant information and by querying experts about different seed and plant industries (see Appendix I for questionnaire used). Recent comprehensive public information on the seed and plant industries is limited and it is necessary to present an anecdotal analysis rather than a detailed, statistically supported analysis of the industry.

For sound public policy and business management involving intellectual property rights on plants and seeds, it is essential to factor the perspective of the general public into the processes. Public issues include the concentration of companies in the seed industry and the genetic diversity of cultivated plant species. Public interest issues concerning the plant and seed industries and intellectual property issues were examined by reviewing the published literature and interviewing individuals who raise these issues and industry experts responses to these concerns.

INTELLECTUAL PROPERTY STATUTES IN THE US

The incorporation of patent laws into the early legislative history of the US did not presuppose their application to plants and agricultural crops although the country was primarily agrarian and early political leaders such as Washington and Jefferson were recognized for their agricultural prowess. In fact, most early patents and more than 50,000 patents issued by the Patent Office from 1790 to 1887 were related to agriculture (Putnam and Evenson, 1983). As plant and variety development became predictable and the basis for major industrial enterprise in the 20th century, it is not surprising that protection of intellectual property was sought to reward the innovator and to be an incentive to continued innovation. In this section, applicable statutes are briefly described and discussed to identify potentially important features which may influence the role of intellectual property in the future of plant and seed industries. It is assumed that the "sister" report will probe these statutes more deeply.

Plant Patent Act of 1930: The essence of the Plant Patent Act of 1930 (PPA hereafter) was to authorize the United States Patent and Trademark Office (USPTO hereafter) to grant patents on distinct and new plant varieties propagated vegetatively except tubers. This exception excluded potatoes and Jerusalem artichokes, for example. A plant patent endows the owner with the right to exclude others from asexually reproducing the plant or selling or

using the plant so produced. The procedures and rules associated with general patents are applicable unless there is an exemption under PPA. A plant patent has only one claim, that relating to the variety described in the patent. The variety claimed must be named and the name will be examined for uniqueness.

The success of Luther Burbank in developing new varieties of asexually propagated plants and his strong personal stand on statutory protection of breeder's rights was reflective of testimony on this legislation which convinced legislators that these propagation procedures were predictable and reproducible. Burbank died in 1926 so he obviously did not testify at these hearings; however, Thomas Edison did testify and said that "This bill will give us many Burbanks" (U.S. Congress, 1930). There was not agreement that sexually produced crops were predictable and reproducible.

Generally, Plant Patents are on ornamental and orchard crops with roses being granted the largest number of patents (Table I; Williams, 1984). There have been more than 6000 Plant Patents issued under PPA which averages to slightly more than 100 per year (Schlosser, 1987). Each of the last 4 years the USPTO has granted more than 200 plant patents. This recent rate is higher than the rate from 1972 tO 1983 which ranged from 117 to 261 and averaged 175 (Table II). This higher rate of protection with Plant Patents is indicative of greater concern about protecting patentable plants so that

the innovators benefit from their efforts.

The Plant Variety Protection Act of 1970: Efforts to enact legislation to protect sexually propagated crops increased in the early 1960's and legislation was introduced in 1968 to include these crops under PPA. For a series of reasons, this bill was not forwarded to the Senate for a vote. The reasons which contributed to the failure of this bill included the position of a presidential commission on patents that rejected the patent system as an appropriate mechanism for plant variety protection (Perrin, Hunnings and Ihnen, 1983) and concerns by the USDA and the state agricultural experiment stations that patenting plant varieties would undermine the development of new varieties (Ruttan, 1982 and U.S. Senate, 1968). In 1969, new legislation was introduced which resulted in the Plant Variety Protection Act of 1970 (PVPA hereafter) and authorized the US Department of Agriculture to grant Plant Variety Protection Certificates (PVP Certificates hereafter) on new varieties of sexually propagated crops. Strictly interpreted, these Certificates are not patents. However, they resemble patents and the constitutional basis for PVPA was clearly the patent clause. Accordingly, in this report discussions about patents usually include PVP Certificates unless a particular distinction between patents and PVP Certificates is being made.

The PVPA had 2 primary purposes when it was enacted. First, breeding techniques had developed so that varieties

could be reproduced uniformly and property rights would stimulate further investment in innovation. The second reason for PVPA was to qualify for admission to an international convention, the Union for the Protection of New Varieties of Plants (UPOV). Admission to this convention was important to provide international protection of plant varieties developed in the US and, likewise, to encourage the distribution of varieties developed outside the US.

There are important features of the PVP Certificates which distinguish them from utility patents or plant patents (PPA). First, PVP Certificates are granted by the Plant Variety Protection Office (PVPO hereafter) in the USDA rather than the USPTO in the Department of Commerce. This organization structure links the protection process to agriculture which can be important in distinguishing the patentability of varieties and the selection of personnel for the examination of Certificate applications. Further, there is a requirement to deposit seed for each PVP Variety and the deposit is placed in the National Seed Storage Laboratory which is part of the USDA. When the PVP Certificate expires, the organizational structure makes the deposited seed a resource for the National Plant Germplasm Collection. There is no requirement for coordination between the PVPO and the USPTO which can be confusing to applicants and others.

The owner of a PVP Certificate can control the following activities:.

1. The sales of the variety

2. The importation of the variety

3. The sexual multiplication of the variety as a step in marketing.

4. Use of the variety for producing a hybrid or different variety.

These activities are clearly specified based on the process of developing varieties and the business of selling seeds. These specifics make the interpretation of the statute clearer in some respects than the general patent statutes and diminish the role of litigation and case law in defining the statute (Lesser and Masson, 1983). For example, it is possible to specify that a PVP Variety can only be sold as a class of certified seed. This stipulation makes it possible to detect administratively unauthorized sales of named PVP Varieties through the Federal and state seed laws.

There are specific exemptions incorporated into PVPA which have a historical basis, but presently are major concerns about PVPA protection of intellectual property rights. There is an exemption often called the farmers' exemption which allows the farmer to save seed from a PVP Variety to grow crops on his farm or to sell to other farmers to grow crops. Of course, this right dates back to the beginning of agriculture when a farmer saved most of his seed and used it to trade for goods as well. This remains a common practice in other parts of the developing world although the modern seed industry, a phenomenon of the this century, prevails in the US. This provision of PVPA is discussed

further relative to the seed and plant businesses in the US and the policy of the PVPO in Management of Patents section.

Another exemption with a historical basis is the breeding and research exemption. Plant breeding and variety development have been a partnership between the public sector and business since the development of practical plant breeding in the late 19th century. The early intellectual inquiry into plant genetics at public institutions evolved into practical plant breeding at many of those same institutions. The transfer of varieties to agriculture proceeded through different avenues including crop improvement associations (discussed in the Seed Industry section), farmers and seed companies. The importance of this relationship was recognized during hearings in 1968 to amend PPA to include sexually propagated crops. The USDA testified that "it would threaten the continued existence of its long standing programs for developing new varieties of seeds...." (US Senate, 1968 cited in Claffey,1981). Under PVPA, breeding materials can be used by plant breeders for research purposes although practical applications theoretically are constrained.

Another interesting feature of PVPA is that a PVP Certificate owner can designate whether the variety must be grown as certified seed and the number of generations of certified seed which may be grown beyond breeders seed and still use the PVP designation. This control is intended to maintain the trueness of varieties sold to varieties claimed

in a PVP Certificate. This feature also links the intellectual property rights to a regulatory process. The certification of seed is usually administered by a state agency which applies criteria for certification grown and/or sold in that state. This feature has no parallel linkage in the PPA although the certification of plants is often administered by the same state agency that certifies seed.

General Patent Statutes: Plants were initially excluded from coverage under the general patent statute because they were considered products of nature which by statute are excluded from patents. This position was sustained by the Commissioner of Patents in Ex Parte Latimer, 1889. The first significant departure from this requirement was the amendment to the general patent statutes known as PPA in 1930 (Seay, 1985). Successful efforts to patent products of nature related to antibiotic, vitamin and steroid discoveries since 1967 demonstrate an increasingly positive view regarding their patentability (Misrock, 1987), and coincide with initial efforts to amend PPA to include sexually propagated crops. The next significant change in USPTO policy on life forms resulted from the Chakrabarty v. Diamond ruling by the Supreme Court in 1980 which allowed a patent to be issued on a life form if man had a substantial role in its creation and if other criteria for patentability were met. This new position by the USPTO was followed by the Patent Appeals Board ruling in Ex Parte Hibberd in 1985 allowed the USPTO to issue a patent on a corn plant which contains increased

levels of tryptophan, an amino acid (Van Brunt, 1985).

The opportunity to protect plant related discoveries under the general patent statutes has been followed by more than 40 plant related general patents to date. Examining the patents issued by the USPTO does not reveal enough experience to substantiate major conclusions. It does appear that corn is receiving the largest number of patents and that other major agronomic crops like sunflowers, wheat and soybeans are the important targets (Table III). Another characteristic of general patents is that they contain multiple claims which is distinct from either PPA patents or PVP Certificates which allow only a single claim. Multiple claims present the opportunity to claim unique combinations of characteristics, for example, wheat with unusually high protein content and herbicide resistance.

Further, unlike PPA and PVPA, general patent claims are not restricted to a single variety of a species. This allows claims which could, for example, include all varieties of soybeans which contain a patented characteristic or a particular method for breeding several cereal crops. This situation leads companies to making pragmatic decisions to balance numerous PVP Certificates and Plant Patents against a single general patent. Generalizing from interviews conducted for this report, a widely expressed opinion is that it is less expensive and more certain to obtain a PVP Certificate than a general patent. However, the expense to patent a discovery is a small part of the expense to develop new

varieties and the financial opportunity to profit is dependent on other factors beyond patentability. An example from the pesticide industry demonstrates the complexity of this financial decision. CIBA-GEIGY, a major agricultural chemical company, developed a chemical safener which when applied to sorghum seed protects that seed from an otherwise herbicidal chemical, metolachlor(Dual). Both the safener and the herbicide are patented. Since Funk Seeds International is a division of CIBA-GEIGY and a major supplier of sorghum seed in the US, one obvious decision would be to make the herbicide safener available only on Funk sorghum varieties. This was not the decision that the company made. The safener was introduced on Funk sorghum varieties as Herbishield and soon offered to other sorghum seed companies as Concep. Examining this example more closely reveals that although Funk is the second largest sorghum seed producer, they sold less than 20% of all sorghum seed and that there were important varieties belonging to other companies which could benefit from the safener. Making the safener available to other companies theoretically increased the market for the safener and the herbicide more than 5 fold (Peek, 1987). Similarly, it seems that making a patented genetic characteristic like herbicide resistance available beyond the patent holder's varieties may represent a sound business decision.

The opportunity to cover plant related discoveries with general patents clearly opens the utility of patent case law

to argue a patent and related procedures. For plants, one such case is In re Lundak decision issued by the US Court of Appeals for the Federal Circuit establish that the deposit of a biological specimen in an approved depository as part of the enabling description in a patent must be made by the time a patent issues rather than at the time a patent application is filed with the USPTO (Elman, 1985). This case also demonstrates the reliance of patents on litigation the expense of which is a factor in the consideration of intellectual property protection. The specific example of deposit is discussed later in this section on patent statute.

Seed Certification: There are Federal and state seed laws which are intended to regulate the purity of seed and plants and protect the consumer of seed and plants from improperly labelled and poor quality products. Purity encompasses genetic purity, vitality and contamination with weed seed, disease organisms and insects. The regulatory processes associated with seed certification range from monitoring seed production through several steps including marketing seed. Seed certification can be important for protecting intellectual property. Under PVPA, the PVP Certificate holder can designate whether or not a claimed variety is produced as certified seed and the number of generations this can be done and still use the PVP name. This option can link the PVP Certificate to a regulatory process for which state governments have responsibility and reduces

litigation expenses to the Certificate holder. There is not similar statutory linkage of seed certification to Plant Patents and general patents. However, it is possible to produce patented seed and plants under government certification programs which can assist in the enforcement of patents.

Likewise, unpatented seed and plants can be produced as certified propagules. Potatoes are grown extensively under certification programs. This is an interesting example for this report because potatoes cannot be granted a Plant Patent or a PVP Certificate because they are propagated using tubers which are specifically excluded in both statutes. According to Wochuk (1987), the potato certification process can protect varieties and are very important to his company so that they can sell potato varieties they produce using tissue culture techniques. Plant Genetics' experience demonstrates the feature of seed certification programs which requires certification in every state where the seed are sold and seed laws vary from state to state. The impact of the state to state differences will vary from crop to crop and variety to variety. For example, if a crop or variety is only grown in a few states, the burden of certification is less than if they are grown in many states. Further, if a crop or variety is not certified in a particular state, it may become the outlet for seed which does not meet the certification requirements of states where it is certified. This latter situation should not occur for PVP varieties which require certification to

use the claimed name.

Trademarks: Trademarks are used extensively to uniquely identify products and may be registered by the USPTO and by states. Since 1956, trademarks are not allowed on seed and plant varieties under Federal Seed Act. In fact, it is illegal to assign more than one name to agricultural and vegetable varieties developed today. There are a few varieties which are still grown from before the Federal Seed Act which are marketed under several names. Trademark on a company name is important to distinguish a variety in the marketplace; however, a company can endanger the registration of a trademark if becomes part of the variety name (Williams, 1984; Fehr, 1987)..

From the interviews for this report, there is a battle in progress over trademarks on ornamental crops which are not specifically under Federal Seed Act. There are registered trademarks on some ornamental varieties and some varieties are probably marketed under several names. Expert opinion on this use of trademarks ranges widely, and the outcome will be established from lawsuits during the next 10 years.

Deposit: Deposit is a concept of placing a sample of the claimed patented organism in an approved public depository to assist in the description of the claimed patent. This is very important to patenting life forms because it is extremely difficult to adequately describe a biological discovery to satisfy the enabling requirements of patents. That is a description within the patent which is sufficiently detailed that one trained in the field could reproduce the discovery.

The legal basis for deposit differs depending on the country and statute involved. The concept of deposit of a claimed variety is prescribed in the PVPA statute. The deposited seed are held at the USDA National Seed Storage Laboratory and the deposited sample is periodically replaced by the Certificate holder if its viability diminished. It is anticipated that the Certificate holder will replace this sample for 18 years, the life of the PVP Certificate. Seeds from this deposit are released only if required as part of litigation and the depositor is notified about these "withdrawals". After the PVP certificate expiration, the National Seed Storage Laboratory intends to release these materials to the collections of the National Plant Germplasm System for use and maintenance (Eberhart, 1987).

The deposit concept is established in case law for the PPA and the general patent statute. Therefore, the deposit rules evolve as additional decisions are reached as exemplified in In re Lundak, 1985. This case law basis contrasts to countries where the deposit concept is established in statute consistent with the Budapest Treaty. At a recent international meeting on plant breeders rights, one discussant made the point that PPA and PVPA would have been unnecessary if the deposit concept were established in the US general patent statutes rather than case law. Although this is arguable, many participants in this meeting thought that incorporation of deposit principals in the US patent statutes would reduce litigation involving deposit

(CIOPORA, 1987).

Simply placing a deposit of the claimed discovery in an acceptable center does not preclude other difficulties. Deposits placed in a public depository are available to the public which makes policing a patent more difficult. There are proposed rules from the USPTO circulating presently which include rules on deposit. Among the proposals is the requirement to deposit the inbred varieties of a claimed hybrid. Accordingly, companies making hybrid varieties would probably not use the general patent statutes because it would allow others to easily expropriate these valuable inbred lines to make look alike varieties or for other varieties (Porter, 1987).

THE SEED AND PLANT INDUSTRIES IN THE UNITED STATES

The seed and plant industries in the US are in the business of providing seeds and plants to propagate new plants. The largest market for these products is agriculture, but very visible are the ornamental and nursery products which contribute to the metropolitan landscape. The agricultural seed and plant industries have moved off the farm during the 20th century to become corporate enterprises. This follows millennia of farmers saving and trading seed. Corporations have replaced hobbyists in providing nursery and ornamental products.

Farm expenditures for seed and plants in the US range from $3.22 billion in 1980 to $3.37 billion in 1985 (see Table IV). These expenditures have varied during the 1980's

because of reductions in acres planted in the US (see Table IV and Table VI). This recent pattern follows a pattern during the 1970's when the average annual increase in seed prices ranged from 7 to 18% per unit seed while there was little change in the total volume of seed sold. Inspite of these price increases during the 1970's, seed as an operating cost to the farmer remained from 5 to 7% of the total operating cost (Table V, Claffey, 1981; USDA, 1986b). In 1985/86, US seed exports were $363 million or slightly more than 10% of the on-farm expenditures for seed (USDA, 1987b).

Modern seed and plant companies obtain the varieties which they sell from plant breeding programs. Typically, these plant breeding programs started at the USDA and agricultural universities during the the end of the 19th century and throughout this century. These public programs developed the plant breeding techniques and many of the varieties that fostered the seed and plant industries. Publicly supported research remains important for the variety development of some crops and is essential to the training of professional plant breeders who are employed by industry. Increasingly, plant breeding programs have become private with private plant breeding annual expenditures estimated at $236 million in 1984. This is approximately 18% of all private expenditures for agricltural research (ARI, 1985). It is precisely these increases in private breeding programs which the USDA predicted in hearings leading to passage of both PPA and PVPA. USDA argued that if they performed less

variety development that they would be able to direct more of their effort toward basic aspects of breeding research (Claffey, 1981; Perrin, Hunnings and Ihnen, 1983). NOTE: Although the words imply supporting basic research, the meaning of basic research in 1930 and 1970 is probably quite different. Further, agricultural research was approximately 80% of the Federal research budget in 1939 compared to 2% in 1985 (Herrett and Patterson, 1987).

Although plant breeding is an essential ingredient in the development of new varieties, it does not follow that all companies in the seed and plant industries have plant breeding programs. According to the American Seed Trade Association, no more than 25% of its several hundred members have significant breeding programs (Lambert, 1987). From another related projection, Lesser and Masson (1983) estimated there are more than 1000 companies in the seed industry with approximately 200 having breeding programs. This means there are more than 800 companies producing and distributing seed, but not independently developing new varieties.

There are a range of sources where companies without breeding research obtain their varieties. One traditional source of developed varieties is the USDA and the agricultural experiment stations at universities. It is widely understood that the public commitment to variety development has decreased substantially compared to the

past. This is consistent with the trend of the private sector performing more applied agricultural research and the public sector performing more basic research for agriculture (OTA, 1986). Nevertheless, public development of plant varieties remains important although this commitment varies from crop to crop and state to state. For example, almost all hybrid corn varieties are private (Perrin, Hunnings and Ihnen, 1983); many peanut varieties are developed at universities; and many wheat varieties are still released from public breeding programs and protected with PVP Certificates while there are more varieties introduced from private breeding programs (Siegenthaler, Stepanich and Briggle, 1986; USDA, 1986c). The corn seed and wheat seed industries will be discussed in more detail in the Case Studies section.

Foundation seed companies are another source of varieties for companies without breeding programs. The foundation seed companies are in the business of selling or licensing varieties to other companies. Historically, foundation seed companies exploited breeding materials developed in the public programs to develop new varieties for other seed companies, and sometimes the foundation seed companies have arrangements with public programs or not-for-profit crop improvement associations to produce publicly developed varieties. Increasingly, foundation seed companies have plant breeding programs to develop new varieties. One such company is Waterman Loomis which develops alfalfa varieties which are widely licensed and is one of

approximately 9 companies breeding new alfalfa varieties (Walker, 1987). Another is Holden's Foundation Seed which develops and licenses corn varieties and recently testified that it supplies parent seed for 30 to 40 % of the corn seed sold in the US each year (Pioneer Hi-Bred International v. Holden Foundation Seed, US District Court, 1987). The future of the foundation seed companies is uncertain because of the overall de-emphasis of public variety development although this public priority varies from crop to crop and because of the opportunities for the improvement of crop genetics utilizing biotechnology. This will be discussed more in the Case Study on Biotechnology.

Farmers also have a key role in the seed industry besides being a customer for the finished variety. This role is to produce seed for the seed companies. For example, more than 500,000 acres of corn are harvested for seed annually and almost all of this is grown by farmers. This makes hybrid corn seed production a major crop, and the premium paid for seed attracts the best farmers.

To effectively consider the role of patents and other intellectual property rights in these industries, it is necessary to select and examine specific seed industries. The rationale for selecting particular crops is incorporated into each examination.

CASE STUDIES

Case Study 1: Hybrid Corn Seed Industry

Hybrid corn seed is the largest seed industry in the US with sales to the farmer ranging from $898 million in 1979 to approximately $1.4 billion in 1985 (USDA, 1987a) and export sales in 1986 estimated at almost $89 million (USDA, 1987b). During the 1970's the farmers average cost for hybrid corn seed increased 10% annually. This increase is shown in Table V where the average cost of hybrid corn seed per acre to the farmer was $6.26 in 1971 and $12.41 in 1979. These increases paralleled increases in pesticide and fertilizer costs during the same period (Leibenluft, 1981). These changes in seed cost occurred when the farmer received more per bushel of corn and had higher yields. In 1971 the average price received at harvest was $1.08 per bushel with an average yield of 88.9 bushels per acre and in 1979, $2.52 per bushel with an average yield of 109.5 bushels per acre.

One reason to focus on corn is that the methods used to produce hybrid corn varieties give the plant breeder and his company substantial control over the variety without patents. A hybrid is produced by crossing two carefully selected varieties and the seed produced from this cross is the hybrid variety. For corn, this is relatively easy because the tassle which contains the pollen can be removed from the female parent so that the only pollen in a seed field is from the male parent. Alternatively, there are genes in the female parent which prevent fertilization by pollen it produces. The

developer of the variety knows the parentage of the hybrid variety and many other characteristics of the parents and the hybrid variety. By protecting the parents as trade secrets, developers may use these successful inbreds indefinitely while they develop new inbreds in their breeding programs. The importance of protecting inbred lines as trade secrets was recently demonstrated in Pioneer Hi-bred International v. Holden Foundation Seed. In this lawsuit, Pioneer contended that Holden was using Pioneer inbred corn lines, which were important trade secrets, to produce hybrid corn varieties for sale. Both companies sustained considerable expense to defend their positions over more than 6 years and Pioneer prevailed in a ruling in October 1987. The court records contained more than 5000 pages of transcript and hundreds of highly technical exhibits (Pioneer Hi-bred International v. Holden Foundation Seed, 1987).

Corn seed is produced as a hybrid because hybrid seed results in yields which are dramatically higher than their parents. Commonly, a hybrid will yield more than twice as much grain than its seed parent (Eberhart, 1987). The advantages in hybrid corn seed were recognized by farmers in the 1920's when the first hybrid varieties of corn were sold. Previously, corn varieties were open pollinated populations of plants. There have been projections that open pollinated corn would produce equivalent yields to hybrid varieties if the same amount of research had been performed to develop open pollinated varieties although this is not a generally

held view. Regardless, today, essentially all corn varieties are developed by commercial concerns and the largest commercial breeding effort involves corn with research expenditures estimated to exceed $115 million annually which represents 5 to 7% of the private sector's total investment in agricultural research and almost half of the private sector's investment in plant breeding research (Claffey, 1981; ARI, 1985). For a specific example, Pioneer Hi-Bred Seed reported in its 1986 Annual Report spending 5% (more than $28 million) of their annual corn seed sales on corn research and development which is high by any industry standard. In the same report, they reported having an enviable 38% of the hybrid corn seed market in North America (Pioneer, 1986). A satisfactory financial return is the prime reason that companies are willing to make this investment and the hybrid variety methodology is intrinsic to that return. Companies' parent lines for variety production and breeding research historically are maintained as trade secrets and, consequently, F1 hybrid corn varieties are proprietary. Further, farmers cannot save seed produced by the hybrid variety because the segregating population of plants produced in an F2 generation are not acceptable and they will not yield as well as the F1 hybrid.

The protection of F1 hybrid varieties is specifically excluded under PVPA. Therefore, only inbred parental lines used in hybrid corn breeding and seed production can be protected under the PVPA. Before 1984, only 10 Variety

Certificates for corn inbred lines had been granted while from 1984 through September 1987, 68 Variety Certificates for corn inbred lines were granted (USDA, 1986c and 1987c; Table VIII). Although at least 16 of these recent PVP Certificates were granted to Standard Oil which has reduced its commitment to plant research, there is a much higher commitment by important companies in the hybrid corn seed industry to obtain PVP Certificates on their inbred parents.

The Ex Parte Hibberd ruling by the Board of Patent Appeals in 1985 specifically involved corn seed and clearly opened the possibility for general patents for hybrid corn varieties. Of the approximately 40 general patents granted by the USPTO on plants, at least 11 are on corn (Table III). This level of commitment plus the substantial increase in PVP Certificates on inbred varieties indicate an expectation that both of these intellectual property protections will be utilized by the hybrid corn industry.

When considering the usefulness of patents, it is necessary to examine the life cycle of a patented product. For pharmaceuticals and pesticides, products frequently remain commercially viable long after patents expire resulting in the generic drug industry and the commodity pesticide industry respectively. For corn, average hybrid varieties remain commercial for 6 to 8 years while exceptional varieties will remain commercial for more than 10 years (this estimate was stated by William Schapaugh in personal communications, 1987 and echoed by other industry

experts). Based on a survey of plant breeders (Duvick, 1984), they estimated the average lifetime of a successful hybrid corn cultivar was approximately 7 years and most expect the lifetime to become even shorter in the future. Only rarely would a corn variety remain commercial for the term of a general patent. One such exceptional variety is Pioneer 3370 which has been sold by Pioneer for more than 20 years. The best inbred varieties may have a considerably longer useful lifetime. Some inbreds used presently were selected from breeding populations developed at universities as early as the 1940's. From surveys of public inbreds, the most successful inbreds may be used for 25 to 30 years and, frequently, their initial use follows their initial release by several years (Evenson, 1987).

Recently, the universities have not been directly involved in breeding new hybrid corn varieties although public inbreds are used by companies. The importance of these public inbreds appears to be diminishing so that there were only 21 major public inbred lines in 1984 compared to 40 in 1979 and 38 in 1975 when public inbreds were used to produce as much as 60% of F1 hybrid corn seed (Evenson, 1987). The role of universities to educate students about plant breeding and to perform important fundamental research continues. These critical responsibilities provide the replenishment of expertise and continued innovation in the universities and industry.

These public releases of inbred corn varieties for

private hybrid development were highly important for the development of large and small seed companies that make up as much as 30% of the hybrid corn seed industry (Claffey, 1981; Lesser and Masson, 1983; Evenson, 1987). Typically, these small companies acquire the inbred seed from a foundation seed company and then produce their own varieties for sale usually on a local basis. The foundation seed companies are a key to this segment of the industry and have increased their breeding programs as public breeding programs decreased. PVP Certificates are important to one foundation seed company, Holdens, which has at least 8 on inbred corn varieties. If patents and biotechnology have an increasing role in hybrid corn variety development for small companies, the foundation seed companies are expected to utilize both the PVPA and general patent statutes and to establish relationships to access biotechnology.

There are several other crops which are grown as hybrid varieties like onions and sorghum. Many characteristics of the corn industry fit the sorghum industry, but the onion industry is strongly influenced by the processor similar to that described in the Case Study on Tomatoes.

Case Study 2: Soybean Seed Industry

The value of the soybean seed industry in the US was estimated at $649 million in 1979 and $630 million in 1985 with exports of seed in 1986 estimated at almost $15 million The lower value in 1985 than in 1979 is because almost 8 million fewer acres were planted in 1985 and because seed

cost $1.10 per bushel less than in 1979 (See Table VI and USDA, 1983a; and USDA 1987a). Year to year changes in soybean seed prices from 1980 to 1985 presented in Table VI show a correspondence between the price paid for seed and the price the farmer receives for his crop. The average price the farmer paid for seed is $2 to $3 more than the price paid for crop beans the previous fall. This irregular pattern for the total soybean seed market during the 1980's compares to the 1970's when the farmers' average cost for seed increased 13.3% annually which was average for all seeds during that decade (Table V, Claffey, 1981; Lesser and Masson, 1983).

The value of the soybean seed industry represents sales transactions plus the value of seed planted by the farmer from his soybeans stored from the previous year's harvest. Farmer retained seed is a significant portion of the seed planted. Based on a USDA survey of soybean growers, it is estimated that 46% of the soybeans planted in 1986 were from the growers storage. The amount of grower retained seed planted ranged from 20 to 68% between growing areas (McElroy, 1987). This estimate compares to an estimate by Leibenluft (1981) of 40% during the mid-1970's. The self pollinating characteristic of soybeans, the historical pattern of farmers retaining seed and the established availability of publicly developed varieties allows farmers to use soybeans which they grow and store for planting.

From a survey by Hanway (1976), public varieties dominated private vaieties 3-to-1 in the mid-1970's which

allowed farmers to retain seed of proven varieties. However, this pattern appears to be changing. Evenson(1983) reported that the number of acres planted to private varieties increased more than 3 times from 1976 to 1982. Further, from Table VII, the number of acres planted to proprietary varieties in Indiana has increased from 15% in 1977 to 46% in 1986 (Brim, 1987). Coupled with the fact that PVP Certificates assigned to the private sector in 1985 and 1986 dominate the public sector assignments almost 8.5-to-1 (Brim, 1987), private varieties are substantially more important to soybean growers than 10 years ago. Unfortunately, the USDA stopped making soybean variety surveys in 1983 and not all states survey soybeans varieties planted. Thus, it is difficult to make more general conclusions about PVP protected variety plantings based on more current information.

Soybeans may be a strong indicator of industries' view of PVPA because this crop has received 427 PVP Certificates since the law was passed. This is almost 23% of all PVP Certificates issued and more than 2 times the second highest recipient, peas (See Table VIII). Annually the number of PVP Certificates on soybean varieties has increased very significantly with 126 issued during the 7 years from 1973 to 1979 and 89 issued during 1985 and 1986. The proportion assigned to industry has predominated with industry receiving 70% during the earlier period and 84% during the latter period (USDA, 1986c; USDA, 1987c). .

The commitment of private industry to soybean variety development in the US has increased dramatically during this same period with the number of soybean breeders in industry increasing from 2 in 1966 to 63 in 1984 at 30 companies (Table IX, Brim, 1987; Kalton and Richardson, 1983). Several reports have concluded that the PVPA was instrumental in establishing the incentive for the privatization of soybean breeding and variety development (Claffey, 1981; Perrin, Hunnings and Ihnen, 1983; Lesser and Masson, 1983; Evenson, 1983; Evenson, 1987). Experience in the 1980's, a difficult time for agriculture and its suppliers, continues to support the important role of PVPA in private soybean variety development.

Concern by the soybean seed industry about farmer retained seed is very serious based on interviews with several business people. Besides data presented earlier in this Case, Williams(1987) cited a comparison between the results of a soybean variety survey in Missouri and the sales of a PVP Certificate protected variety from Asgrow which indicated the company sold less than 40% of that variety grown in the state.

General patents may be important for soybeans. There are at least 5 general patents related to soybean breeding issued by the USPTO which places soybeans within a group of agronomic crops which have about half as many patents as corn (Table III). Companies' concerns about the research and farmers' exemption associated with PVPA could cause them to

seek more general patents on their discoveries. However, the present uncertainty about general patents will cause this to occur gradually if at all.

Case Study 3: Wheat Seed Industry

Wheat was grown on 79 million acres in the US in 1984 with an estimated total farm value exceeding of $7 billion. From 1980 to 1985, the total acreage has averaged 81 million acres ranging from 88 million acres to 76 million acres. The export of wheat from 1980 to 1985 has averaged 55.8% of production ranging from 39.2 to 63.6 % (See Table X and USDA, 1987a; USDA, 1983a).

In recent years the value of wheat seed planted by farmers has ranged from $455 million in 1985 to $632 million in 1981 and averaged $530 million from 1980 to 1985 (See Table X and USDA, 1983a; USDA, 1983b; USDA, 1986a). Similar to soybeans, it is important to note that value rather than sales of seed is used for wheat. This is because a significant part of the wheat seed planted is from the farmers' bin rather than a purchase by the farmer. From a USDA survey of wheat growers, it is estimated that approximately 40% of the wheat planted in 1986 was grower retained seed. The growing areas surveyed ranged from 2% to 64% (McElroy, 1987). Leibenluft (1981) estimated that farmers produced about 65% of their own wheat seed in the mid-1970's. One reason which contributes to this practice is the the ease of retaining seed. Wheat can be readily retrieved directly from the farmer's storage bin for planting with minimal

concern for reduced seed viability, germination and emergence. Farmers know the growing experience of the seed in his bins including drought and disease. If the farmer suspects his seed is poor, he can purchase seed from a commercial source. Soybeans compared to wheat are considered more fragile and benefit from careful handling and conditioning.

Concern about farmer retained seed has been translated into research over many years to develop effective techniques and superior hybrid varieties which could not be retained by the farmer for seed. Inspite of these efforts, the USDA survey of wheat varieties grown in 1979 and 1984 reported only minor acreages of hybrid wheat varieties and in 1984 the recorded acreage of hybrid wheat was less than 0.1% of the total (Brigggle, Strauss, Hamilton and Howse, 1981; Siegenthaler, Stepanich and Briggle, 1986).

Regardless, the survey of wheat varieties grown in 1984 reveals more wheat varieties from private development and frequent protection of varieties with PVP Certificates (Table XI; Brigggle, Strauss, Hamilton and Howse, 1981; Siegenthaler, Stepanich and Briggle, 1986; USDA, 1986c; USDA, 1987c). In 1984, 18.7% of the varieties identified were privately developed compared to 10.2% in 1979. This percentage increase occurred when there were 59 more varieties reported in 1984 than in 1979. This increase in private varieties reflects a high level of research expenditures relative to sales by the private sector.

Estimates from a survey by Perrin, Kunnings and Ihnen, 1983, showed companies investing 20 to 30% of their sales into research from 1965 to 1979 which is very high by industry standards. Although the research investment by the private sector as a percentage of seed sales appears to have declined since 1975, the total private sector investment in wheat breeding appears to be increasing (Evenson, 1987). This higher level of industry development of wheat varieties is also reflected in the 159 PVP Certificates granted for wheat varieties since 1972 (Table VIII; Evans, 1987). This number is approximately 8.5% of the total PVP Certificates granted and 72.3% of these were granted to the private sector.

Because the high level of private research expenditure on wheat preceded the increase on soybeans and PVPA, it is probable that the early expenditures were directed toward hybrid wheat variety development. The present research expenditure level reflects a continuing private effort which is enhanced by variety protection with PVP Certificates (Perrin, Kunnings and Ihnen, 1983; Evenson, 1987).

Public wheat varieties still dominate those grown in the US. Increasingly, public varieties, however, are covered by PVP Certificates. Five of the top 10 wheat varieties in 1984 had PVP Certificates and 4 of those were assigned to public institutions. These same 5 varieties were planted on 18% of the total acres planted to wheat. In 1979, only 2 of the top 10 varieties were covered by PVP Certificates and both were assigned to public institutions (Siegenthaler, Stepanich and

Briggle, 1986; Briggle, Strauss, Hamilton and Howse, 1981).

The USDA Agricultural Research Service has performed wheat variety surveys every 5 years since 1919 so it is possible to determine the lifetime of a variety. From interviews for this report, the opinion was that wheat varieties followed a similar pattern to corn as cited in Case Study 1 with the average variety lasting 5 to 8 years. From Duvick's survey (Duvick, 1984), breeders estimated the average cultivar lifespan at 9 years with an expectation by the majority of breeders that the cultivar lifespan will become shorter. Better disease resistance and insect resistance are frequently the characteristics which cause a farmer to select a new variety of wheat seed. One exceptional variety is Triumph which was first distributed by an Oklahoma farmer in 1940 and grown on 5.6 million acres in 1949, 6.3 million acres in 1959 and 1.3 million acres in 1979 (Briggle, Strauss, Hamilton and Howse, 1981). Similar to corn, exceptional varieties can be expected to be grown beyond the term of general patents and PVP Certificates.

Data on wheat production is frequently aggregated; however, not all wheat is the same nor does it sell for the same price in domestic and world markets. Wheat is differentiated by classes which are determined by their species or subspecies of the genus Triticum and by the end use of the particular class. For example, Durum wheat is used to make pasta while common wheat is used to make flour for bread and baking. The processing quality of wheat is

determined by the form of starch that the wheat seed contains. These distinct processing characteristics may be increasingly important if they are incorporated into new varieties. When considering this possibility, which was suggested by several interviewees for this report, it was noted that recently enzymes have been added before baking to change the baking characteristics of gluten in flour resulting in soft pastries, e.g., soft batch cookies (Bishop, 1986). If the starch form in wheat varieties were changed genetically, this distinction could change the system in which wheat is grown and distributed. It is possible more and more wheat would be grown under contract as described later in the Tomato Case Study or is commonly practiced in winter wheat grown in California. Accordingly, the role of the processor in the selection of varieties could increase. It is possible that related discoveries could be patented under the general patent statutes or protected with a PVP Certificate. Interestingly, Pioneer has patented a wheat variety with a general patent and protected the same variety with a PVP Certificate which demonstrates that protection under one statute does not necessarily exclude protection under the other. The management of Pioneer indicated that their purpose in pursuing a general patent was to gain experience in that type of intellectual property protection, and are undecided whether this double protection results in any particular advatages (Frey, 1987; Porter, 1987).

Case Study 4: Tomato Seed Industry

The tomato seed industry is 2 distinct industries-tomato varieties grown for processing and tomato varieties grown for fresh market. There are further distinctions within these 2 broad groups; however, these are practical categories for data available. This case more comprehensively describes and discusses the processing tomato seed industry because features of this industry may reflect the future of other seed industries.

The tomato processing industry is primarily located in California with 217,000 acres grown in 1985. This is 82% of the acres and 85% of the total US production. This compares to 1971 when approximately the same total number of acres were planted but only 168,000 acres were grown in California which was 64% of the US production (USDA, 1987a; USDA, 1973). Plant breeding programs for processing tomato variety development have resided in the univeristies, seed companies and processing companies with universities less involved in variety development since the mid-1970's. There are open pollinated* tomato varieties and F1 hybrid tomato varieties sold to farmers growing this crop. From one estimate,

* Open pollinated is the term used in the industry although these are are self pollinated. Self pollinated means that the pollen which fertilizes the egg comes from the same plant. For self pollinated tomatoes, the pollen and egg come from the same flower. The production of F1 hybrid tomato varieties requires manual removal of the pollen sacs from the female parent and hand fertilization of the female parent with pollen from a distinctly different variety.

approximately 30 to 35% of the processing tomato acreage is F1 hybrid varieties and 65 to 70% is open pollinated varieties (Thomas, 1987). These comparisons are remarkable when the seed prices are compared. The current prices for open pollinated varieties is approximately $15 per pound which is the same price as 20 years ago. The current price for hybrid varieties is approximately $200 per pound. The market for open pollinated varieties for processing is approximately $2.5 million and the market for hybrid varieties is approximately $7 million. When the planting rates for the varieties are factored in, the farmers seed cost per acre is approximately $14 for open pollinated varieties and $90 for hybrid varieties. Why are there these large price differences? The primary reason is that hybrid seed production requires substantial manual labor to pollinate the seed parent, and the reason the price for hybrid seed is this low is that production is off-shore in Taiwan and Southeast Asia.

Why do farmers plant expensive hybrid tomato seed? There are two major reasons for this. The first is the role of the processor in the planting decision. The second is the particular characteristics of the varieties. The processor contracts with the grower to buy his crop before it is planted. The contract specifies the variety planted, the

planting date, the number of acres planted and the price paid per ton of the harvested crop. These contracts reduce many risks a farmer has in an open market which is critical with a perishable crop like tomatoes. However, it introduces several constraints which are conditions of production. Secondly, several characteristics of hybrid varieties make them desireable such as high yield and processing quality and effective genetic disease resistance. For example, if one parent is homozygous for a dominant gene for nematode resistance, hybrid varieties using this parent will also be resistant to nematodes. This is practically important because it reduces a farmer's cost for nematicides, and, in California, regulations of the Department of Food and Agriculture require the disclosure labeling of a processed tomato product on which a nematicide has been used. This regulatory requirement, of course, will influence the variety designated in a processor/grower contract.

What are the implications of intellectual property opportunities for tomato varieties grown for processing? Since 1980, open pollinated varieties and inbred parents could be covered under PVPA through an amendment to the Act which added tomatoes among other crops. The PVPO has granted 28 PVP Certificates for tomatoes since that amendment. The inbred parents used in hybrid production may also be granted a PVP Certificate. There is skepticism that PVP Certificates on inbreds are useful, and the description in the application may disclose approaches which are better protected as trade

secrets (Thomas, 1987). The PVP Certificate on open pollinated varieties does provide some protection and, importantly, preserves the variety name. This name protection is not a trademark, but since seed varieties cannot be protected by trademarks under Federal Seed Law this may be a close approximation

F1 hybrid tomato varieties cannot be protected under PPA or PVPA like other hybrid varieties discussed earlier. However, hybrid tomato varieties may be protected under general patents statutes. There seem to be reservations about the desireability of this protection because a single tomato variety may not justify the expense (Thomas, 1987). This concern is different than for seed like corn or soybeans perhaps because of the average tomato variety lifetime is shorter (4 to 5 years) and the annual sales from a single variety is lower. Circumstances do exist which may utilize general patent statutes for tomatoes like cell and tissue culture techniques, unexpected combinations of disease resistance, and unexpected, useful quality characteristics. This last area of discovery is especially important to the tomato processor. It is, therefore, not surprising to observe processors like H.J. Heinz, Campbell Soup and DelMonte establishing alliances with biotechnology companies to perform research on crops which they process (Van Brunt and Klausner, 1987).

Case Study 5: The Biotechnology Industry

A substantial part of the biotechnology industry is targeting applications to crop agriculture through the development of plants and seed with superior genetic characteristics. It is estimated that research expenditures by industry for applications of biotechnology to crop agriculture were $90 million in 1985 which represented almost 13% of the industrial investment in biotechnology. This estimate compares with $73 million in 1984 (NSF, 1987). These estimates may be conservative because, for example, the Agricultural Research Institute projected more than $100 million in industrial crop biotechnology research in 1982 (ARI, 1985). These expenditures for crop agriculture biotechnology research compare to 1982 industry research expenditures for plant breeding ranging from $115 million (Kalton and Richardson, 1984) to $236 million (ARI, 1985). This comparison of research expenditures supports the view that successful biotechnology research will have a major impact on plant genetics and the seed farmers plant. It follows then that the patent strategies of the performers of this research will constitute a significant component in the future role of patents in the seed and plant industries.

It is important to understand that this biotechnology research includes direct manipulation of plants and research with microorganisms which may be used to benefit plants. Separating research expenditures by plant versus microorganism is artificial because there is technology

development needed for plant manipulation and much of this development is done in microbial systems. For example, there are at least 12 companies trying to improve Bacillus thuringiensis, a bacterium, to control insects (Herrett and Patterson, 1987). At least one company, Plant Genetic Systems, has succeeded in incorporating the insect toxin gene directly into tobacco resulting in a plant which is resistant to lepidopterous insects (Newmark, 1987). This continuum from microbial to plant biotechnology has important intellectual property implications. PVPA and PPA are only applicable to higher plants and are not applicable to microorganisms like fungi and bacteria. Therefore, only the general patent statutes provide possible intellectual property protection in the organisms where technology is currently being developed.

The particular technology used in biotechnology research will influence intellectual property strategies of companies. Based on the NSF surveys, rDNA/RNA research accounts for approximately 2/3 of the research expenditures for agricultural biotechnology (NSF, 1987). Accordingly, general patent statutes are primarily applicable to discoveries from this research although only a few patents have issued. Further, the case law established in biomedical applications of rDNA/RNA will provide important precedents for agricultural applications and corporate patent strategies. This is important because of the technological lead of biomedicine and the level of research expenditure. For example, biomedical research expenditures for rDNA/RNA were

approximately 4 times those in crop agriculture (NSF, 1987). Utility of r-DNA in specific crop varieties is ahead. This is supported by the fact that in 1986 the first field trials in the US of plants manipulated with r-DNA were approved by the USDA. Since the patents related to the discoveries in these field tests have not issued, tests which receive regulatory approval will be indicative of patents related to rDNA applications for crop agriculture. Since a commercial plant variety requires minimally 3 years of extensive (multiple sites, commercial production practices and different environmental conditions) field testing and typically 5 or more years of field testing before sales, the commercial availability of products will be a much later indicator of patent activity but will indicate which discoveries are valuable.

Another important area of technology for crop agriculture is plant cell and tissue culture. There are at least 11 US patents issued in this area of technology. Since this area of technology is critical to rDNA applications to plants and has a longer history, it is not surprising to find this level of patent activity.

The companies performing biotechnology research for crop agriculture generally fit into 3 categories. First are the small entrepreneurial companies having major commitments to research and progressively moving products to market. Second are multidivisional companies having one division involved in agriculture. This group includes companies like Monsanto,

DuPont and CIBA-GEIGY. Third are companies whose primary business is food and agriculture which includes companies like Pioneer and Cargill. Food companies like Campbell Soup and RJR Nabisco are included in this latter group and are becoming increasingly involved in applications of biotechnology to crops (Van Brunt and Klausner, 1987).

There are other factors which indicate that general patents will be used extensively to protect agricultural biotechnology inventions. Multidivisional companies in agricultural chemical and pharmaceutical industry have extensive experience and expertise in the development and management of general patents in the US and internationally. This experience base results in these companies favoring the general patents in the US for agricultural biotechnology. This favored view of general patents is reflected in the small entrepreneurial companies because these companies often are performing contract research for these larger companies. Based on one estimate, at least 38% of research at these entrepreneurial companies is funded through contracts (Arthur Young, 1986; Arthur Young, 1987). Since these multidivisional companies favor general patents, general patent protection for discoveries resulting from their contract research will be favored. Further, the venture capital sector which has provided startup resources for most of the entrpreneurial companies emphasize patent protection for high technology companies and are more familiar with general patent statutes than with more specialized Plant

Patents and PVP Certificates. From interviews for this report, scientists and patent attorneys and agents expect general patents to provide the strongest protection for biotechnology discoveries. However, a widely shared view in the biotechnology industry is that general patent protection is superior to PPA or PVPA protection although more difficult and expensive to obtain.

As biotechnolgy companies have become more integrated in their activities, for example, acquiring seed companies or developing plant breeding programs, their awareness of PPA and PVPA has led them to consider this intellectual property protection useful similar to more experienced plant and seed companies (Goodman, 1987).

It is important to consider the research areas of crop biotechnology which will become the topics of general patents. The author has compiled examples in Table XII to indicate the subject of these patents which may be issued during the next 10 years (Herrett and Patterson, 1987). These inventions include the incorporation of new genetic traits like herbicide resistance and enhanced amounts of nutritional components like amino acids (This is one claim of the Hibberd et al. patent). Eventually, patent applications involving multiple gene characteristics, deletion of characteristics not desired and modification of nutritional components like storage proteins will be filed in the USPTO.

One concern expressed about plant biotechnology and general patents by university and industrial scientists is

that the performance of research using patented materials is an infringement. This contrasts to the PVPA which includes an exemption that allows research with plant varieties assigned PVP Certificates and contrasts to the history of plant variety development in the public sector. The extent of this concern is not determined although there are indications that suitable arrangements can provide research access to patented materials. For at least 4 decades universities have done research on patented agricultural chemicals and pharmaceuticals. For example, patented herbicides were used extensively to understand the biochemistry of photosynthetic electron transport and, more recently, herbicide resistance. Patented insecticides affecting cholinseterase have been useful for understanding neurobiology and neurotoxicity. This research has progressed sometimes supported by grants from the patent holder and sometimes without the knowledge of the patent holder. The author is unaware of any infringement proceedings ever initiated against researchers to stop this kind of research. With this precedent, companies like Monsanto and Calgene have made genetically engineered materials from the research available to university research laboratories. Specifically, Monsanto has provided a strain of Pseudomonas containing an insect toxin gene available to numerous university researchers and Calgene makes their glyphosate (an herbicide) resistance gene available under a research only license. It is too early to determine whether or not this will become common practice for agricultural

biotechnology companies.

MANAGEMENT OF PATENTS

Companies in the seed and plant industries need to manage their intellectual property. For plant variety development and agriculture generally the role of the public sector through the Land Grant Universities and USDA is strongly ingrained in providing breeding material and finished varieties to seedsmen and farmers that the value of the incorporated technology is often considered a community right rather than property of value. Further, since plants are products of nature, some argue that plants are in the public domain (Mooney, 1979). This was the original view of the USPTO (Seay, 1985). However, usually there is little resemblance between wild plants found in nature and cultivated varieties. Wild tomatoes stretch one's imagination to envision that fruit sliced in a garden salad, and the poisonous of this relative of nightshade was argued publicly in the early 1800's. The heritage of the modern corn plant has been a major intellectual pursuit. The development of cultivated varieties is the result of the intervention of man in the reproductive process to enhance particular characteristics, and this intervention by man is the very inventive process which can be the basis of a patent, for example, the development of a new soybean variety which is resistant to a new race of Phytophthora root rot.

As described earlier, from a legal perspective in the US, it is possible for an individual or his or her assignee

to seek a plant patent, a utility patent or a plant variety certificate under different statutes. It is also possible to maintain a variety and the processes used to make it as trade secrets. The registration of a trademark may also dove-tail into the development and marketing of a new variety. From a practical perspective, it is not clear that a single approach to protecting intellectual property will make the best business sense over the next 10 years. Accordingly, companies that are actively involved in obtaining intellectual property rights are using multiple approaches to protect their research investments. Following are some of the key issues influencing their decision processes:

Crop: Intellectual property issues vary from crop to crop. The reproductive processes of plants are not all the same. Simplistically, there are open pollinated plants and self pollinated plants. Crops which are open pollinated range from corn to alfalfa to apples. Field corn varieties are essentially all F1 hybrids in the US, and because they are hybrids, they are excluded from coverage under either the Plant Patent Act or the Plant Variety Protection Act. Inbreds used in the production of hybrid corn varieties are protectable under PVPA but are usually protected as trade secrets which was discussed earlier. Thus, the general patent statutes are the only patent opportunity for finished F1 hybrid corn varieties. This contrasts to apples which are covered under the PPA because they are vegetatively

propagated and alfalfa which can be covered under the PVPA (As of December 1,1987, there are 47 variety certificates issued for alfalfa varieties, Table VIII). This range of crops and opportunities for intellectual property protection demonstrates that because crops are open pollinated is not a categorization from which to generalize about intellectual property rights for plants.

Self pollinated plants include crops like tomatoes, soybeans, cotton and wheat. Again, the patent coverage available in the US to breeders covers the range of possibilities. Tomatoes were originally excluded from the PVPA in 1970 and included through an amendment in 1980. Subsequently, 28 Variety Certificate have been issued on tomatoes. Commercial efforts to develop hybrid varieties have paralleled the increased opportunity for patent coverage for self-pollinated varieties. Like corn, inbreds used in variety production could be covered under PVPA, but commercially acceptable varieties could be covered as well. The hybrid tomato varieties may be covered under the general patent statutes although none have been issued. Soybeans have received the largest number of Variety Certificates from the PVPO of any crop (430 as of December 1,1987, Table VIII), and this protection reflects the substantial increase in commercial soybean breeding programs. Comparatively, wheat has received 159 Variety Certificates (Table VIII). Companies are challenged to continue private wheat breeding programs because of the market size, the sales margins and the

availability of excellent public varieties. One target of these private programs has been to develop genetic hybrids and sometimes chemically induced hybrids. These hybrid approaches on wheat may be and are covered under general patent statutes. However, the value of hybrids is not widely accepted with hybrids making up less than 1% of the varieties planted in 1983/84 (Siegenthaler, Stepanich and Briggle, 1986).

Although crops can be classified by their natural reproductive processes, it is the practical method by which a crop propagule is made that determines the patent protection available for that crop. Further, new methods to produce propagules are potentially patentable under the general patent statutes. For companies breeding several crops, intellectual property management is more complex because of the different approaches between crops.

Farmer's Exemption: One unique feature of the PVPA is the "farmers exemption" which was described earlier in the Statutes and Case Studies is a reflection of farmers' practices from the beginning of agriculture. From the seedsmen's perspective, this allows the farmer to produce and use proprietary varieties without risk of infringing on the property rights of the PVP Certificate holder. In effect, the farmer can compete directly with the seedsman that has developed the variety as long as the primary occupation of the farmer is production agriculture.

In a recent Louisiana court case (Asgrow v. Kunkel,

1987), a farmer sold more than 45% of his production of a soybean variety having a PVP Certificate as seed to other farmers. Although the seed sold was enough to plant almost 50,000 acres of soybeans, the court held that because more than 50% of the farmer's income, which included income from other crops, was from farming, his primary occupation was a farmer. Therefore, the farmer was within the farmers' exemption and did not infringe upon the rights of the PVP Certificate-holder. This decision is being appealed by Asgrow.

There are many anecdotes about this practice of farmers producing seed of different crops and varieties having PVP Certificates. Analytical information measuring this practice would be very useful; unfortunately, it is scarce. One PVP Certificate holder projected his company sold less than 40% of its soybean variety grown in Missouri based on comparisons of sales revenues and state estimates of acreage planted to that variety (Williams, 1987). Based on a USDA survey of 1986 plantings, only 54% of the soybean seed planted was purchased and only 60% of wheat seed planted was purchased (McElroy, 1987). The net effect of the farmers' exemption is that PVP Certificate holders will seldom profit as extensively as their varieties are grown. These lower profit expectations can result in a reduced research investment by companies, and potentially slower and/or less frequent advances in variety improvements. However, the extent to which the farmers exemption is critical to the existence and level of

commitment to private breeding is not determined.

Although reductions in breeding programs are one way to manage the difficulties with the farmers' exemption, companies can seek general patents on their varieties because there is no farmer or research exemption as prescribed under PVPA. Based on the interviews for this report and patents issued, companies are approaching general patents cautiously. Two reasons for this are the uncertainty of general patent protection and the difficulty of policing infringers. Some consider general patents more difficult to obtain than Plant Patents or PVP Certificates although the USPTO believes there is no difference (Bagwell, 1987).

Pioneer Hi-Bred International has obtained a PVP Certificate and a general patent on the same wheat variety. The primary reason this company pursued both approaches was to gain experience with the general patent process. There were no particular features of the discovery which resulted in the general patent application (Frey,1987).

Another approach to the "farmers' exemption" is to seek specific limitations would make it clear to both seedsmen and farmers when there is and is not an infringement of a PVP Certificate. This can be partly accomplished through case law. However, based on the above cited case in Louisiana and others, companies appear to judge the present climate of the courts unfavorable to their idea of limits on the "farmers' exemption". Further, extensive litigation against farmers is frequently a concern to agribusiness companies because the

unfavorable publicity can be manifested in reduced product sales. A successful legal challenge can be a business disaster.

Another approach to establish limitations on the "farmers' exemption" is to seek legislative or rule-making changes in the practice. The Plant Variety Protection Advisory Board, a 14 member board appointed by the Secretary of Agriculture to advise the Commissioner of the Plant Variety Protection Office, has appointed a study group to examine the "farmers' exemption" because they receive more complaints about that feature of PVPA than any other, and because they are concerned about it eventually undermining the PVPA in favor of the general patent statute. This sub-committee is in the early fact-finding phase of their study (Evans, 1987). The results of their study could be useful in elucidating and measuring the problems with the farmers' exemption and also suggesting solutions.

Litigation: Litigation is clearly part of establishing farmers' exemption. It is intrinsic to the patent process and resulting case law helps define the limits of patents. This is demonstrated to those in biotechnology with cases related to the Cohen-Boyer patents, the Chakrabarty v. Diamond decision by the Supreme Court and, intimately associated with crop agriculture, the Ex Parte Hibberd ruling and the Lundak decision. Pragmatically, litigation is not without substantial cost and companies seeking patent coverage need to be prepared to defend their claims. A company should

expect to spend a minimum of $100,000 to $200,000 for each patent involved in litigation (Feit, 1987; Williams, 1988). From interviews, many companies over the next 10 years expect to expend considerable effort establishing and defending their patent positions. Not all patents on all plant related claims can commercially support these costs and not all patents will be consequential to establishing a patent position. The complexion of these changes will be partly reflected in patent applications that are abandoned and patents no longer maintained. Experience is minimal to enumerate any patterns. However, it is reasonable that crops where the profit margins are small and varieties for which the total market is small may not justify protection for financial reasons. Contrarily, it may be precisely those crops and varieties which require the profit incentive to support continued innovation in crop improvement.

Licenses: One way to resolve patent litigation is to reach an acceptable licensing agreement between the involved parties. These licenses must be filed with the USPTO and are subject to regulatory review by the Justice Department to assure that there is no unfair competition or other unacceptable consequences from the license (Ridpath, 1987; Hoff, 1986). Such licenses are not uncommon with patents on agrichemicals like metribuzin (Sencor and Lexone), a soybean herbicide, and carbofuran (Furadan), a corn rootworm insecticide, being cross licensed between the litigants in 2 different, unrelated patent cases (Grimes, 1987).

Patent conflict can be avoided through licenses between companies. For example, in the "biotechnology industry", large companies have negotiated licenses with small companies for discoveries and products in particular areas of research and development. Crop agricultural biotechnology follows the general pattern with larger companies supporting a portfolio of research projects at smaller biotechnology companies. One interesting arrangement is between Pioneer Hi-Bred; Molecular Genetics and American Cyanamid. American Cyanamid has a proprietary class of herbicides which they would like used on corn. Molecular Genetics has an outstanding research program on cell and tissue culture of corn to develop herbicide resistant corn lines. Pioneer has a powerful corn breeding program and the dominant market position for hybrid corn seed. Each company will benefit if they develop commercially successful varieties (Bishop, 1985). This arrangement is a "strategic relationship" and this concept has proved very successful in other industries like microelectronics and the personal computer industry (McKenna, 1986). It appears that many companies in the agricultural biotechnology industry are pursuing alliances which provide them continuing access to new technology (Arthur Young, 1987). Central to these alliances are licenses to patents (or projected patents) so that a company is not locked out from critical technology. This may partly reflect the agrichemical companies in this industry because these companies traditionally license production technology to each other and sell chemical intermediates to each other, but

their products containing the acquired technology or intermediates compete with each other in the market.

There are numerous examples of finished varieties of plants and crop varieties being licensed to other companies for production and sales. In the hybrid corn seed industry, Holden's Foundation Seeds has built a company which licenses their inbred lines and hybrid varieties to other companies. For alfalfa, Waterman Loomis has likewise derived considerable income from similar licenses on their varieties. One excellent example from the public sector are licenses to plant varieties from the University of California patented under PPA. In 1986, the University received almost $1.2 million in royalties from plant varieties patented and more than half of the royalties were from strawberry varieties which are grown around the world (Ditzel, 1987).

R & D Use of Patented Plants and Seed: Neither the general patent statute or PPA provide for research uses of patents which they issue. This contrasts sharply with the PVPA which allows the use of varieties having PVP Certificates for research purposes. This research exemption is controversial within and outside the different seed industries. The controversy from outside centers on concerns about genetic diversity and are discussed in the section on Genetic Diversity. Those companies having plant breeding research programs are concerned about improvements they have developed being used directly in commercial breeding programs by their competitors. Effectively, one company performs the

research, and another uses it without compensation. One interviewee commented cynically that ", The only way you will catch anyone under the research exemption is if they put their label on your bag of seed." Another interviewee emphasized that a company which bases its research program on the commercial varieties of competitors will consistently be a follower into the market (Crosbie, 1987). From another perspective, however, during the 1930's several outstanding inbred corn varieties, which were used to make successful hybrid corn varieties, were developed from high performing open pollinated corn varieties (Evenson, 1987).

Deposit: The role of a biological deposit is to complement the verbal description of a discovery. This is described and discussed in the earlier section on the Statutes. Relating this to companies' management of intellectual property is very important because of the risk a company takes when it makes a biological deposit of, for example, seed. Under PVPA, the conditions of deposit are part of the statute and access to the deposited seed requires permission from the Certificate holder.

These deposit conditions contrast to those used by the USPTO and mandated by the Budapest Treaty which require unrestricted access to deposited seed after a patent has issued. These conditions of deposit are considered substantially more risky than under PVPA and provide a mechanism through which important patents may be pirated. The proof of pirating shifts from the documented access to

courts where pirating would need to be proved. Accordingly, the expenses from litigation resulting from deposit requirements could be substantially greater under the general patent statute.

Market: The term market size encompasses several closely interrelated elements of variety development - annual sales, product life cycle, product profitability and research investment. There must be adequate profit potential to be an incentive for companies to invest in research. Costs to develop a maize variety are estimated at $900,000 and $600,000 for a soybean or wheat variety and these actual costs must be discounted over a several year period (Brim, 1987). To pay back these expenses and a reasonable profit for the risk taken requires a substantial market for a particular variety during its commercial lifetime. The actual commercial life of a variety places financial constraints on variety commercialization. Interviewees indicated an average variety of corn, soybeans or wheat may remain commercial from 5 to 10 years while an occasional extraordinary variety, such as Pioneer Hi-Bred 3780, may remain commercial for upto 20 years. Varieties of less intensively bred crops, such as peanuts, may remain commercial for 8 to 10 years. These product life cycles contrast to vegetatively propagated plants covered by PPA where varieties are commonly commercial when the patent on them expires (Bolusky, 1987). The profitability of seed for crop production depends on the competition in the marketplace, and is definitely less for

crops where the farmer can plant seed out of his storage bins. Marketshare is usually very important for variety success and profitability. Less obviously, the production yields can be very important to the profitability of a particular variety. For example, a hybrid corn seed from a production field yielding 20 bushels per acre has more than twice unit cost of a field yielding 40 bushels per acre. This was a real problem for early single cross corn hybrids which resulted in the use of double cross hybrids until the mid-1960's (Evenson, 1987). In conclusion, the total financial opportunity for a new varieties of a particular crop will influence the investment in breeding programs. The willingness to invest will be reflected in the number of general patents, PVP certificates and Plant Patents issued on that particular plant species.

PUBLIC ISSUES

Patents and intellectual property laws reflect societal goals to encourage new ideas and to enhance the welfare of the general public. The general patent statutes do this across different technical, social and economic circumstances (Lesser and Masson, 1983). The Plant Patent Act and the Plant Variety Protection Act reflect more specific societal goals because they involve plants and seeds which are essential to the caloric and nutritional needs of society. PPA was enacted during important restructuring of public agricultural research making a transition from practical to scientific research. This restructuring

was important to the success of public agricultural research (Evenson, 1983). The USDA supported PPA and testified that it would allow them to direct their research efforts toward basic research (Perrin, Hunnings and Ihnen, 1983). Different societal goals are reflected in PVPA compared to PPA. There was an exemption of research uses of protected varieties from infringement because research serves a public need, and there was an allowance for farmers to retain seed for planting from protected varieties they grow which continues a practice with long historical precedence.

Since there is now the potential to protect plant varieties and related discoveries with general patents, it is necessary to consider the public interest ramifications of this change. Two obvious issues related to this are the preservation of the genetic diversity in cultivated plants and the the concentration of plant variety development in the private sector both of which will be discussed further in the next 2 sections of this report. These are not new issues which have arisen as a consequence of biotechnology and patents, but have been debated while new roles and structures for agricultural research have evolved over the last 20 years (for example, National Academy of Sciences,1972; Mooney, 1979; Claffey, 1981; Ruttan, 1982; Winrock, 1982; Lesser and Masson, 1983; Evenson, 1983; National Research Council, 1984; Doyle, 1985; National Research Council, 1987). So, in the larger context of an "appropriate public agricultural research agenda," the impact of intellectual property rights

on plant genetic diversity and private plant variety development need consideration. However, each of these issues is highly complex and intellectual property rights are among numerous other factors influencing these issues.

These issues are under reexamination when the US public has a moderately favorable view of biotechnology applications to plant agriculture, but limited technology literacy and biotechnology and plant breeding understanding (OTA, 1987; Evenson, 1987b). Coincidentally, the US public understanding of agriculture has diminished greatly as exemplified by the dramatic reduction in the farm population from earlier in the 20th century. The reduced understanding of agriculture is accompanied by reduced political influence from rural areas and agriculture. The public consideration of intellectual property issues related to plant breeding are precarious under these circumstances. Further, the fields of patents and intellectual property are specialized areas of law and business, and some individuals who the general public expects to understand patents do not. This is demonstrated by written testimony provided by Orville Freeman, former Secretary of Agriculture, during hearings to expand patents to include sexually produced crops under the PPA in 1968. Secretary Freeman wrote "...the patent can be used for no other purpose than to harass and frighten off would-be competition."(Lesser and Mason, 1983). This kind of public statement demonstrates a serious misunderstandng of intellectual property. This links patents to monopolies, and the negative public

perception of monopolies and the intervention of the US government for more than 100 years to protect the public from monopolies.

Another timely public issue is international competitiveness. Based on 1985/86 data, the US exported approximately $360 million in plants and seeds annually which is more than 10% of the on-farm sales of seeds and plants (USDA, 1987b). The US government and US companies are considered world leaders in agricultural applications of biotechnolgy. Yet, Duffey(1987) expressed grave concerns about the willingness of industry to continue investing in plant biotechnology and plant breeding if their inventions cannot be protected internationally with effective patents so that innovative companies can recover their investment with a reasonable profit. The international patent issue is too broad to analyze in this report; therefore, it is simply identified here.

INDUSTRY CONCENTRATION

There is concern about the concentration of crop variety development in a small number of companies. This concern results from the public policy to privatize plant and seed variety development which is consistent with the present emphasis of public agricultural research policy; from the competitive advantage that patents and patent-like protection provides to companies; and from the acquisition of seed companies by multinational corporations. The objective of this concern is that the public interest will be ignored if a

small number of companies are determining which seed varieties are commercially available. The failure to consider the public interest is a central premise of the book, "Hard Tomatoes, Hard Times" which examines the development of tomato varieties for mechanical harvesting (Hightower, 1978). Possible consequences of concentration include reduced innovation, higher seed costs to the farmer, direct linkage of seed purchases to other inputs like pesticides and, as discussed in the next section, reduced genetic diversity and concomitantly increased susceptibility of crops to pestilence ence. These concerns are expressed by interest groups like the National Sharecroppers and the Environmental Policy Institute, farmer groups and certain international organizations like the Food and Agriculture Organization (FAO) of the United Nations (Claffey, 1981; Doyle, 1985; Fowler, 1980; Lesser and Masson, 1983; Mooney, 1979; Perrin, Hunnings and Ihnen, 1983). Likewise, these groups have generally opposed patents on plants, seeds and life forms because there is potential to strengthen the competitive position of companies that develop and distribute new varieties and to not adequately represent the publics' interests. From another perspective, since the US public policy to privatize variety development is established, there is or should be concern about the public's interest if the incentives for private variety development like patents were eliminated or diluted.

Studies have examined and analyzed several dimensions of

the seed industry structure to determine the extent of concentration in the industry. Overall, these studies have concluded that there is not unusual concentration in the seed industry and that many industries which are considered very competitive have considerably greater concentration than the seed industry. Accordingly, the untoward results of concentration in the seed industry would not be expected based on the information available when these studies were performed (Claffey,1981; Lesser and Masson, 1983; Perrin, Hunnings and Ihnen, 1983). These studies do reflect most seed company acquisitions by multinational chemical firms which started in the late 1960's through the late 1970's. As stated earlier, the average price for seed to the farmer increased 13% over this same period (Table V).

These studies do not reflect changes in seed prices and acquisitions and realignments in the seed industry during this decade. For example, in the hybrid corn seed industry, the market leader, Pioneer Hi-Bred which is an independent public corporation, increased its market share to 37% in 1985 and 38% in 1986. This compares to 23.8% in 1973 and 32.9% in 1979. In 1986, the leading 7 companies in the hybrid corn seed industry combined market share was 72%. In 1973, the market share of the 8 leading companies was 74% and 69% in 1979 (Miller Agrivertical Unit, 1979 and 1980 and Pioneer, 1987). In Table VI, the changes in seed prices for corn, wheat and soybeans from 1980 to 1985 are presented (There is more discussion about the price of seed for these crops under

the Case Studies). If there were reduced market competition, increased prices per unit of production would be expected, but has not happened. It appears that commodity prices and seed supply are significantly more important determinants of seed price than patents and company ownership. This conclusion is for wheat and soybeans and a more detailed study would be necessary to extend this conclusion to other seeds and plants.

Other measures of competition in the marketplace include the number of products available and the level of research investment. From the Case Study on Wheat in this report, there are actually 59 more varieties reported in 1984 than in 1979 and 178 of these, 41%, were not reported in 1979. Over this same period, the acreage planted to privately developed wheat varieties doubled (Briggle, Strauss, Hamilton and Howse, 1981; Siegenthaler, Stepanich and Briggle, 1986). From the Case Study on Soybeans, the number of private soybean breeders has increased from 6 in 1971 to 63 in 1984 which represents a major increased research investment by the private sector. The result of this research is exemplified by a 3-fold increase in soybean acreage planted to private varieties in Indiana in 1985 compared to 1977 (Brim, 1987). The survey by Duvick (1984) reveals three key points on the quantity of varieties available for 5 major crops. First, the varieties important in 1969-70 were considerably less important in 1979-80. For example, only 2 of the 6 leading soybean varieties in 1970 were among the 10 leading varieties

in 1980. Second, the leading varieties in 1979-80 were planted on a smaller proportion of the total acreage than in 1969-70. For example, the 6 most popular corn cultivars were planted on 71% of the acres in 1970 but only 43 in 1980. Third, plant breeders estimate that the average life span of varieties of these 5 crops will become shorter. This information indicates rapid product changes which are indicative of a competitive market.

The private research investment in plant breeding research appears to have increased significantly with one estimate of $80 million in 1979 (Perrin, Kunnings and Ihnen, 1983) increasing to $236 million in 1984 (ARI, 1985). Added to these amounts are the investments in biotechnology research for crop improvement which in 1985 approached $100 million (NSF, 1987). These investments in biotechnology research were not reflected in the earlier studies on competition in the seed industry. When added to the private research investment in plant breeding, there is a very substantial increase in research investment which is directed toward improvement in crop genetics. A high level of research signals product innovation which is indicative of a competitive industry.

Since major multinational corporations are major investors in biotechnology research for crop agriculture, it is necessary to comment on their effect on plant breeding and the structure of the plant and seed industries. Earlier in this section, analyses indicated there was no unusual

concentration within the seed industries from acquisitions of seed companies by multinational corporations during the 1960's and 1970's. At least 2 major corporations, Lubrizol and ICI, have made acquisitions of existing seed companies to become major components in the overall seed industry. Expectations from biotechnology research probably contributed to these business decisions. In other major multinational corporations especially DuPont and Monsanto, the commitment to biotechnology research for crop agriculture is highly visible, but business commitment to the seed and plant industries is less visible. The evolution in biotechnology applications to crop agriculture will be an important component in the future structure of the plant and seed industries (Herrett and Patterson, 1987). During these changes, patent activities including PVP Certificates will be indicators of technology management by industry because of the patent experience of multinational corporations and the applicability of general patents to biotechnology.

From the information presented, the increased level of research investment and the increased number of varieties available to the farmer are indicative of a competitive industry from which considerable innovation should be projected. However, there are crops which private industry has not aggressively pursued; there are crops which rely on public breeding programs for new varieties; and there are crops which do not have public or private breeding programs providing the variety innovation which farmers might like to

have. Although this situation is not new to variety development, there is a need to continually monitor breeding efforts and, perhaps, support public breeding programs for variety development or provide incentives beyond patents for the private sector to develop breeding programs. The structure of the seed and plant industry will continue to change as biotechnology among other factors exerts greater influence on plant breeding. There are no obvious alarms indicating that the publics' interests are currently ignored during these changes. However, because changes are anticipated, periodic examination of the seed and plant industries can determine favorable and unfavorable changes.

GENETIC DIVERSITY

The continued availability of germplasm containing useful genes is a major public concern that is frequently heard and is periodically analyzed as, among others, in the OTA Report on Technologies to Maintain Biological Diversity (OTA, 1987). Specific to plants, there is concern that cultivated varieties will have a narrow genetic base and higher potential for crop disaster from a common susceptibility to pestilence (NAS, 1972; OTA, 1987 and currently there is a NAS committee reviewing the issues of genetic diversity of cultivated crops, Evenson, 1987b). The Southern corn leaf blight which attacked the US corn crop in 1969 and 1970 is a practical example of widespread susceptibility of commercial corn varieties to a specific disease. During this particular episode, some growing areas

experienced 70% losses and overall loss estimates were 15%. The example of Southern corn leaf blight is only a recent example of a crop disaster from pestilence and many more are doumented throughout history. One closely linked to the American heritage of the 19th century is the Irish potato famine from 1845 to 1847. The decimation of the potato crop, a primary staple in the Irish diet, was caused by late blight disease. This famine resulted in approximately 750,000 deaths and the immigration of hundreds of thousands of Irish to the United States.

The Southern corn leaf blight epidemic had a genetic basis because disease susceptibility was closely linked to a specific male sterile gene in seed parents used in hybrid corn seed production throughout the hybrid corn seed industry. The speed with which the industry determined the cause of the problem and modified its seed production practices to provide resistant varieties was as spectacular as the devastation of this disease itself. This solution depended heavily on an intimate knowledge of the genetic material and a system which allowed effective dissemination of the required breeding material to produce resistant varieties. The hybrid breeding system itself contributed substantially to the solution because simply using seed parents without disease susceptibility in production resulted in disease resistant varieties in the first generation.

The Southern corn leaf blight epidemic and the Irish potato famine are not isolated incidents. Breeders are in a

constant race to stay ahead of changes in the disease organisms. For example, soybean breeders are constantly incorporating resistance to new strains of nematodes and to new strains of Phytophthora root rot. Wheat breeders are incorporating resistance to rust and mildew. The ability to breed resistance into crops is a phenomenon of the 20th century with modern plant breeding programs and biotechnology having improved disease resistance as primary objectives.

The experience with Southern corn leaf blight demonstrates 2 key points. First, disease can devastate a susceptible crop or variety with too narrow of a genetic base. Second, disease susceptibility can be overcome if the necessary genes and breeding systems are available to develop disease resistant varieties. This latter point is central to the issue of preserving the present genetic diversity of plants so that it can be exploited in future cultivated varieties. Often, new genes including genes for disease and insect resistance are derived from plants collected around the world and maintained in germplasm banks. After geneticists characterize collected plants in these germplasm banks, the opportunity to utilize these plants in commercial breeding programs increases.

Assuming it is desireable and important to maintain genetic diversity, what impact will patents and intellectual property rights have on genetic diversity? It depends on the specific patent coverage a plant related discovery has. Under PVPA, there is an exemption for research uses of plants

covered by PVP Certificates. Accordingly, researchers can conduct research with PVP protected materials without infringing on the PVP Certificate holders rights. Under both PPA and the general patent statutes there are no exemptions for research uses of protected discoveries and researchers using these materials without permission would infringe on the rights of the patent older. Under the general patent statutes, this would include varieties and other related patented technology which could be used to maintain genetic diversity, for example, breeding methods and preservation techniques, for example, plant cell and tissue culture.

The use of patented materials and methods in research appears to be critical in the genetic diversity issue. If the private sector makes a conscientious effort not to infringe on patents, potentially greater genetic diversity could be incorporated into commercial varieties. Duvick in his survey of plant breeders revealed greater attention to genetic diversity and genetic reserves by these researchers which supported his conclusion that commercial varieties are genetically more broadly based than in 1970. He cautioned that more varieties are necessary to provide an even broader genetic base in commercial varieties and that particular breeding strategies result in varieties which are more susceptible to catastrophic disease (Duvick, 1984; Duvick, 1986).

As plant biotechnology research continues, there will be even greater genetic diversity in crop varieties as new genes

and gene combinations are incorporated into varieties. However, it is anticipated many of these discoveries in the private and even the public sector will be the subject of patents (Table XII). The extent to which these discoveries will be available for research is being determined now. As cited earlier, there are precedents in the agricultural chemical industry and examples in the agricultural biotechnology industry which allow research on patented materials. Further, the patent process is intended to make information public rather than leaving it undisclosed for another to rediscover. One estimate from the USPTO indicates that 80% of the information diclosed in patents is disclosed no where else in the public literature (USPTO, 1987).

The availability of patented materials for research does not extend to commercial applications of these materials. There are opportunities to license patents for commercial utility. Although the licensing process is private, it does provide a mechanism to utilize the genetic diversity which may be patented. Licensing decisions are motivated by the opportunity to profit financially which does not necesarily represent a public benefit. In retrospect, it is revealing and perhaps reassuring to ponder the Southern corn leaf blight situation. The hybrid corn seed industry depends heavily on trade secrets; yet, the industry quickly solved a problem to benefit the public and, coincidently, to benefit the companies in the industry.

The issues of genetic diversity are complex and not

singularly focused on patents. Another very real concern about genetic diversity is the freedom with which germplasm is exchanged between countries. Certain countries for specific crops consider their natural populations of these plants a resource which has value and should be traded. There is validity to this claim; however, these plants remain an unmineable resource without efforts to characterize these materials and to reduce them to a useable forms. The maintenance of genetic diveristy is seriously challenged by countries that do not participate in international genetic exchange and it seriously endangers the efforts of CIMMYT, IRRI and othe international germplasm programs. Conditions which relate to this exchange are similar to those on patents and, therefore, it is not surprising that some international centers and programs oppose patents because of concern for a diverse gene pool for plant breeding (OTA, 1987).

The management of genetic diversity and the genetic susceptibility of commercial plant varieties will continue to be a debateable issue into the foreseeable future. Central to this issue is adequately funded international programs to maintain genetic diversity in natural populations and old and foreign commercial varieties. The private sector appears solidly behind these efforts in principle while the developed and developing countries have contrary positions which interfere with a unified approach to the maintenance of genetic diversity (OTA, 1987).

SUMMARY AND CONCLUSIONS

The Chakrabarty decision by the US Supreme Court followed by the Ex Parte Hibberd ruling by the Patent Appeals Board clearly communicated to industry and the general public that discoveries related to plants and seeds are eligible for patents under the general patent statute. This became the third patent or patent-like statute which the plant and seed industries in the US have available to protect their discoveries. This change is consistent with the changes in technology which underlie these industries. The Plant Patent Act was enacted in 1930 with strong supporting testimony that plants propagated using vegetative techniques were predictable. In 1970 the Plant Variety Protection Act was enacted to protect varieties produced using sexual breeding techniques because the outcome was now predictable. During the period between these 2 acts, the understanding of genetics, plant breeding and the physiology of seed growth and development increased significantly due partly to an increased emphasis on scientifically based agricultural research. Since PVPA was enacted, the field of molecular biology has developed and the "biotechnology industry" has come into existence to exploit practical applications of molecular biology in crops. It is the predictability, novelty and useful applications of molecular biology through the interventiion of human that established a basis for protection of discoveries with general patents during this decade.

These apparent increased opportunities for protecting intellectual property have paralleled substantial increases in private research investment in plant breeding with the amounts increasing to approximately 18 % of the private investment in agricultural research. Additionally, the private sector has invested in biotechnology research for crop agriculture which is between 5 and 10% of the private investment in agricultural research. These levels of private research are accompanied by increases in privately developed varieties of seeds and plants. This trend is exemplified by the significantly increased acreages of wheat and soybeans planted to private varieties during the last decade. It is important to remember that financial profit motivates the the development of new varieties by the private sector. Therefore, developers of new varieties intend to recoup their pre-market expenses through sizeable and profitable markets. This motivating force is different than the development of plant varieties by public institutions which historically were central in the development of new plant varieties. The public made a substantial investment in variety development and the producer and distributor of seeds and plants did not have to recoup the pre-market R&D expenses.

The increased opportunities to protect intellectual property and the increased private investment in plant breeding and crop directed biotechnology reflect a public policy of placing seed and plant variety development in the private sector. The role of the USDA and other public

institutions involved in seed and plant variety development has changed with the privatization of these activities. The public institutions have increased their commitment to basic research, and have diminished their role in seed and plant development. This reduced public commitment is exemplified by the decreased, relatively small number of PVP Certificates issued to public institutions (Table VIII). Although the effectiveness with which this basic research is performed and the adequacy of resources to do so is debated, the public interest in variety development and related issues is a concern. Among these public concerns are the genetic diversity of cultivated plant varieties and the implications of privatizing variety development like the concentration of the industry in fewer companies. There are strong indications that patents are contributing to innovation in industry especially for major crops and that these public concerns are not currently problems resulting from patents. The present situation is not static and should be carefully followed to assist in public policy. It is alarming that the extensive information on varieties which the USDA collected earlier is frequently no longer collected on a national basis because variety development has a reduced role in the USDA. This gap needs to be corrected to respond to issues involving patents.

There is a potential gap in technology investment for minor crops compared to major crops. The number of patents and PVP Certificates on major crops dominate the efforts to obtain intellectual property protection. This is not

surprising; however, this situation is indicative of less research and, eventually, innovation for lesser crops. If this indication is accurate, there should be concern and perhaps active, publicly based or funded variety development for lesser crops although it is contrary to the present public policy on plant variety development.

Since major parts of the seed and plant industry do not have substantial plant breeding research or biotechnology research, it is anticipated that there will be restructuring within these segments because they relied very heavily on public research for new varieties. The role of strategic alliances to access new technology and varieties could become more important for these compnies and for larger companies. Since companies in the seed, plant and biotechnology industries are not certain of the value of their and other intellectual property, there is an eagerness to establish licenses to transfer technology which may be crucial in the future. This is a trend which will continue for several years and may become an integral part of doing business as it is in the chemical industry.

It appears that the existing statutes, PPA and PVPA, will continue to be utilized by the plant and seed industries during the next decade. Based on the number of plant patents and PVP certificates granted annually and the plans of entities in these industries, these two statues will probably be used more frequently in the future. Although PPA can provide legal precedents for PVPA, trademark preservation

appears to capture major concern from the holders of Plant Patents. Although seed varieties cannot have registered trademarks under federal seed trade law, variety naming is important to variety developers to establish unique identification. The name of the company can receive a trademark and, used in conjunction with the variety name, distinguishes a variety in the marketplace.

The higher expenditures required to develop varieties will influence companies to work on major and profitable crops with plant breeding. The expenditures for biotechnology research will have the same effect. Accordingly, there will be increasing efforts to obtain general patents as well as Plant Patents and PVP Certificates. Many of the kinds of discoveries expected in the plant biotechnology area will only be protectable with general patents. Therefore, because of the technology and the level of research investment, major increases in general patents related to crop biotechnology are expected over the next 10 years. This projection is a reflection of the recent experience in the USPTO. Because biomedical applications of biotechnology are ahead of crop applications, it is expected that general patents in biomedicine will establish important precedents upon which patent strategies for agricultural biotechnology will be based. The kinds of discoveries involved are projected in Table XII. One useful aspect of patents is that they do provide an information base on which both business decisions and public policy decisions may be based. Following these

trends should be undertaken as part of the agricultural research policy process. Since field tests of plants modified using rDNA require regulatory approval, these approvals will precede patents and will provide early insight into successful research.

There are projections that the structure of agriculture may change as a consequence of new varieties developed and grown to the specifications of food companies. The tomato industry may be the prototype of this different structure. If so, the risks that the individual farmer takes may be reduced as more crops are grown under contract. The public policy implications of this change would be very broad as are the implications for the seed industries.

Generally, the privatization of plant and seed variety development has resulted more private research to develop varieties. Although the impact has not been uniform, similar discrepancies existed when variety developemt was centered in the public sector. The opportunity to protect discoveries with patents or patent-like protection has had a positive impact during this transition inspite of the imperfections in thee enabling statutes and case law. The future trend in intellectual property protection for plants will show an increase for PVP Certificates and Plant Patents and an acceleration of related general patents. It is anticipated that the phase of acceleration will follow several years of caution toward the general patent statutes. The opportunity to manage litigation from plant related discoveries through

seed certification systems will very likely elevate the importance of these systems in spite of their state to state differences.

There is a clear need to follow different trends related to the seed and plant industries to assure that the public interests especially safe and abundant food are met.

APPENDIX I. QUESTIONAIRE FOR OTA PATENT REPORT

The following questions reflect the type of information collected in the telephone interviews of contacts. Not all of the questions are relevant to all of the contacts. Further, information from public interest groups and universities overlapped partially with the responses to these questions, but were unique to their particular interests and perspectives.

Which crops does your company work with?

Are patents important to protecting varieties of these crops? Which ones?

What is the average life span of a _____ variety in the marketplace?

How many commercially significant varieties are grown today? How many of these are patented or have variety certificates?

What kind of patents are most important to your company?

Is the situation adequately clear regarding plant related patents to take a single approach? Do you expect the situation to clarify sufficiently to change your present position? When?

Do you expect to perform more or less R & D as a consequence of patents?

Do you expect to license patents or patented products from other companies or organizations?

Does the potential cost of patent litigation concern you? Would those costs influence your business decisions and your patent strategy? In what ways?

Does the broader potential for patents change the role of public institutions role in supporting your crops?

For which 5 crops will patents be most important? Why?

What 5 traits will be the most important for patent coverage? Why?

What important changes could occur that would influence your views on patents?

What will be the role of patents for large established seed companies? small seed companies? biotechnology companies?

How will the farmer and the consumer fare in all of this?

How do you believe patents will influence your industry segment?

Will the primary users of the products/crops have an increasing or decreasing impact on the variety selection by the farmer? Describe.

Do you have other major concerns about the protection of plant varieties through patents and variety certificates? What are these concerns? Please explain.

APPENDIX II. SPECIFIC CONTACTS FOR OTA PATENT REPORT

The following list includes the names of the organizations which were contacted during the information gathering phase for this report. The cooperation of individuals within these organizations is greatly appreciated.

Advanced Genetic Sciences

Agricultural Research Institute

Agrigenetics

Agracetus

American Association of Nurserymen

American Cyanamid

American Seed Trade Association

Arthur Young High Technology Group

Asgrow

Biotechnica International

Calgene

CIBA-GEIGY Corporation

CIOPORA

Cornell University

Crop Genetics International

Dekalb Pfizer

DelMonte Corporation

DNA Plant Technology

DuPont

Environmental Policy Institute

Funk Seeds International

Garst Seed Company

General Foods

W. R. Grace

Holdens Foundation Seed Company

Hutton Associates

ICI Americas

Lubrizol

Mobay Chemical Company

Molecular Genetics

Monsanto

National Association of Plant Patent Owners

Native Plants

North Carolina Crop Improvement Association

North Carolina State University

Peto Seeds Inc.

Pioneer Hi-Bred International

Plant Genetics, Inc.

Sandoz

University of California

U. S. Patent and Trademark Office

USDA, National Seed Storage Laboratory

USDA, National Agricultural Library

USDA, Office of Plant Variety Certificates

USDA, Economic Research Service

Upjohn Co.

Waterman Loomis

Economic Growth Center, Yale University

Table I. Plant Patents Issued by the US Patent and Trademark Office

	1931-1962		1963-1968		1969-1973		1974-1978		1979-1983		1984-1987	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
AfricanViolet	9	.4	0	.0	12	2.2	45	4.8	54	6.7	49	5.4
Almond	6	.3	15	2.3	9	1.6	11	1.2	15	1.9	7	.8
Apple	55	2.5	22	3.4	17	3.1	36	3.8	33	4.1	17	1.9
Azalea	49	2.2	40	6.2	34	6.1	27	2.9	7	.9	4	.4
Begonia	4	.2	0	.0	7	1.3	28	3.0	7	.9	11	1.2
Camellia	38	1.7	5	.8	4	.7	1	.1	0	.0	1	.1
Carnation	50	2.3	6	.9	11	2.0	33	3.5	10	1.2	83	9.2
Chrysanthemum	133	6.0	38	5.9	68	12.2	155	16.4	99	12.3	128	14.1
Fuchsia	27	1.2	3	.5	0	.0	0	.0	0	.0	1	.1
Gladiolus	30	1.4	53	8.2	8	1.4	6	.6	0	.0	0	.0
Grape	10	.5	8	1.2	5	.9	9	1.0	16	2.0	14	1.5
Kalanchoe	0	.0	0	.0	5	.9	33	3.5	14	1.7	30	3.3
Nectarine	59	2.7	14	2.2	25	4.5	29	3.1	17	2.1	23	2.5
Peach	151	6.8	29	4.5	29	5.2	30	3.2	34	4.2	30	3.3
Plum	25	1.1	18	2.8	6	1.1	16	1.7	14	1.7	31	3.4
Poinsetta	13	.6	14	2.2	17	3.1	22	2.3	0	.0	15	1.7
Rose	1,061	48.1	232	35.9	141	25.4	239	25.3	232	28.7	201	22.2
Strawberry	30	1.4	8	1.2	13	2.3	18	1.9	21	2.6	14	1.5
SubTotal	1,750		505		411		738		573		659	
Total Issued	2,207		647		556		946		808	9.08	907	9.07
Annual Avg.	53		108		111		189		162		227	

SOURCE: American Association of Nurserymen, Plant Patents with Common Names, 1931-1962; 1963-1968; 1969-1973; 1974-1978. (Washington, DC: American Association of Nurserymen, 1963; 1969; 1974; 1981) and Classification and Search Support System (CASSIS), USPTO.

Table II. Number of Plant Patents Issued by the USPTO, 1972-1987

Year	Number of Plant Patents Issued
1987	229
1986	224
1985	242
1984	212
1983	198
1982	174
1981	188
1980	117
1979	131
1978	186
1977	173
1976	177
1975	150
1974	261
1973	132
1972	218

SOURCE: Official Gazette, 1972 to 1987.

Table III. General Patents Issued on Plants, Number and Crop

Crop	Number
Corn	11*
Sunflowers	6
Soybeans	5
Wheat	5*
Other	17
Total	42

* Two patents are included in both corn and wheat because the claims include both crops. Therefore, there are 42 patents.

SOURCE: Information for this table was compiled from CASSIS search of Class 800 (multicellular organisms) and cross references to this class and then reviewing the Official Gazette and the identified patent.

Table IV. Expenses: Seed Purchased, United States, 1971-85

Year	Seed Purchased * (Million Dollars)
1971	1,072
1972	1,115
1973	1.617
1974	1,941
1975	2,138
1976	2,366
1977	2,484
1978	2,638
1979	2,904
1980	3.220
1981	3,428
1982	3,172
1983	2,987
1984	3,447
1985	3,369

* Includes bulbs, plants and trees.

SOURCE: U.S. Department of Agriculture, Agricultural Statistics, 1986

TABLE V. CHANGE IN SEED PRICES, 1971-80

PERIOD	HYBRID CORN	WINTER WHEAT	SOYBEANS
	PERCENT		
1971-72	20	5	21
1972-73	14	11	7
1973-74	3	142	68
1974-75	13	4	9
1975-76	46	(19)	11
1976-77	0	(2)	(30)
1977-78	10	(27)	76
1978-79	8	34	(12)
1979-80	6	25	4
1971-80	142	177	146
AVERAGE ANNUAL CHANGE	10	17.8	13.3

SOURCE: USDA Agricultural Statistics, 1972 and 1979, Washington, DC as cited in Claffey, 1981.

TABLE VI. SOYBEAN, WHEAT AND CORN SEED COST: 1980 - 1985

US SOYBEAN SEED COST, 1980-85

	1980	1981	1982	1983	1984	1985
SEED COST ($/ACRE)	7.87	10.45	8.15	7.98	10.08	8.74
HARVEST PRICE ($/BUSHEL)	7.72	5.95	5.13	7.95	6.05	4.86
AVERAGE YIELD (BUSHELS/ACRE)	25.9	30.2	31.9	25.7	27.5	33.5

US CORN SEED COST, 1980-85

	1980	1981	1982	1983	1984	1985
SEED COST ($/ACRE)	14.24	16.28	17.27	16.65	18.03	18.47
HARVEST PRICE ($/BUSHEL)	3.10	2.38	2.14	3.21	2.58	2.22
AVERAGE YIELD (BUSHELS/ACRE)	90.1	109.3	114.6	78.8	105.8	117.0

US WHEAT SEED COST, 1980-85

	1980	1981	1982	1983	1984	1985
SEED COST ($/ACRE)	6.51	7.16	6.56	6.37	6.49	6.02
HARVEST PRICE ($/BUSHEL)	3.76	3.63	3.39	3.48	3.37	2.92
AVERAGE YIELD (BUSHELS/ACRE)	29.9	31.5	32.6	36.9	34.0	32.9

SOURCE: Economic Indicators of the Farm Sector: Costs of Production, 1982 (USDA, ECIFS 2-3) and Economic Indicators of the Farm Sector: Costs of Production, 1985 (USDA, ECIFS 5-1).

Table VII
Percent of total soybean acreage grown to proprietary cultivars in Indiana*

Year	Percent
1977	15.3
1981	36.4
1986	46.3

* USDA Crop Production Report 1983 shows that the acreage grown to proprietary soybean cultivars increased from 10.6% in 1980 to 26.2% in 1983 in IL, IN, IA, MN, MO, NE, OH

SOURCE: Brim, 1987.

TABLE VIII. PVP CERTIFICATES GRANTED. COMPARISON OF CERTIFICATES GRANTED THROUGH 1983 AND GRANTED THROUGH DECEMBER 1,1987

CROP	1971-1983	1971-1987**
SOYBEANS	244 (37)*	430 (59)
PEAS	113 (0)	187 (0)
BEANS	110 (2)	169 (4)
WHEAT	127 (36)	159 (44)
COTTON	102 (13)	151 (21)
CORN	12 (2)	78 (0)
LETTUCE	44 (0)	69 (0)
RYEGRASS	23 (1)	64 (2)
FESCUE	22 (1)	61 (9)
ALFALFA	25 (6)	49 (10)
BARLEY	14 (2)	36 (3)
MARIGOLD	25 (0)	34 (0)
BLUEGRASS	19 (3)	33 (3)
TOMATO	9 (0)	28 (4)
ONION	14 (0)	25 (4)
WATERMELON	10 (1)	24 (6)
TOBACCO	14 (0)	22 (0)
CAULIFLOWER		19 (0)
OATS	16 (8)	21 (12)
RICE	12 (0)	14 (0)
CHINA ASTER	10 (0)	11 (0)

* Number in () indicates the number of public varieties granted PVP Certificates.
** To December 1,1987

SOURCE: Evenson, 1983; Evans, 1987.

Table IX
The size of soybean breeding research by private industry in the U. S. before and after the introduction of plant variety protection laws in 1970

Year	Number of	
	Companies	Breeders
1966	2	2
1971	6	6
1984	30	63

SOURCE: Brim, 1987.

Table X. Wheat Production, Export and Seed Cost: 1980-1985

Year	Seed Cost Acre ($)	Total Seed Value ($ x million)	Total Acres Planted (x million)	Bu Export/ x 100 Bu Production (%)
1980	6.51	526	80.8	63.6
1981	7.16	632	88.3	63.6
1982	6.56	566	86.2	54.6
1983	6.37	487	76.4	59.0
1984	6.49	514	79.2	54.9
1985	6.02	455	75.6	39.2
AVG	6.52	530	81.1	55.8

SOURCE: USDA Agricultural Statistics, 1986; USDA Agricultural Statistics, 1982; USDA Economic Indicators of the Farm Sector: Costs of Production, 1985; USDA Economic Indicators of the Farm Sector: Costs of Production, 1982.

TABLE XI. Leading Wheat Varieties Grown in the US: 1979 and 1984

1979		1984	
Variety Name	% of Acres	Variety Name	% of Acres
Centurk*	6.3	Newton*	6.1
TAM W101	5.3	TAM W-105	6.0
Scout	4.9	Vona*	4.7
Olaf	4.1	Marshall*	3.2
Eagle	3.9	Scout 66	2.6
Scout 66	3.4	Stephens	2.5
Arthur 71*	3.2	Len	2.3
Sage	3.1	Hawk*	2.1
Butte	2.6	Caldwell*	2.0
Era	2.5	Vic	1.9
Arthur	2.5		

* Indicates that named variety is protected by a PVP Certificate. The only private variety listed which is protected by a PVP Certificae is Hawk.

SOURCE: Briggle, Strauss, Hamilton and Howse, 1981; Siegenthaler, Stepanich and Briggle, 1986; USDA, 1986c.

Table XII. PRESENT AND PROBABLE TOPICS OF PLANT BIOTECHNOLOGY PATENTS

PLANT CELL AND TISSUE CULTURE METHODS

SYNTHETIC SEEDS

HERBICIDE RESISTANT PLANTS

DISEASE RESISTANT PLANTS

INSECT RESISTANT PLANTS

IMPROVED NUTRITIONAL QUALITY

MODIFIED OR UNIQUE PROCESSING CHARACTERISTICS

ENVIRONMENTAL RESISTANCE

IMPROVED MULTIGENE CHARACTERISTICS

NEW MULTIGENE CHARACTERISTICS

SPECIFIC GENES

DNA AND RNA VECTORS

GENE EXPRESSION SYSTEMS

TABLE . PVP CERTIFICATES RECEIVED AND ISSUED AS OF OCTOBER 1,1987

YEAR	NUMBER RECEIVED	NUMBER ISSUED
1971	110	0
1972	149	0
1973	102	6
1974	109	98
1975	105	104
1976*	99	113
1977	112	140
1978	106	100
1979	120	88
1980	166	125
1981	177	108
1982	191	153
1983	179	142
1984	157	120
1985	219	155
1986	164	200
1987	214	205

SOURCE: Evans, 1987

TABLE . BREAKDOWN OF CERTIFICATES BY USE CLASS

CLASS	APPLICATIONS RECEIVED		CERTIFICATES ISSUED	
	NUMBER	%	NUMBER	%
AGRICULTURAL	1869	67.3	1223	65.6
ORNAMENTAL	117	4.7	83	4.5
VEGETABLE	693	28.0	558	29.9

SOURCE: Evans, 1987.

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